Resources

PART I

Lectures Prepared

by

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Chapter 1
Introduction

The emphasis of this book will be on analysis: Why resources are used as they are, and what specific steps can be undertaken to use them at a rate that is socially beneficial for all. Our aim is to get an overview of the kinds of problems that are dealt with in natural resource economics, population resource economics, and environmental economics.

So, we will divide this book into three sections:

Section I : Environmental Economics.

Section II : Natural Resource Economics.

Section III : Population Economics.

Environmental economics is the application of the principles of economics to the study of how environmental resources are managed. It is concerned also with how economic institutions and policies can be changed to bring these environmental impacts more into balance with human desires.

It is important to distinguish between positive economics and normative economics. Positive economics is

the study of what is. Normative economics is the study of what ought to be. Positive economics seeks to understand how an economic system actually operates by looking at the way people make decisions in different types of circumstances. In contrast, normative economics involves more than just knowing how things work; it also involves value judgments.

The economic approach to environmental issues is to be contrasted with what might be called the moral approach. According to the latter, environmental degradation is the result of human behavior what is unethical or immoral.

Nature resource economics is the application of economic principles to the study of total economic activities. A fundamental distinction in natural resource economics is that of renewable and nonrenewable resources. The living resources, such as fisheries and timber are renewable, they grow in time according to biological processes. Some nonliving resources are also renewable such as energy. Nonrenewable resources are those for which there are no processes of replenishment; once used they are gone forever such as petroleum reservoirs and nonenergy mineral deposits. The use of nonrenewable resources involves trade-offs between the present and the future. If more oil is

pumped out of an underground deposit this year, less will be available to extract in future years.

The problem of population growth is not simply a problem of number, it is a problem of human welfare and economic development. Rapid population growth can have serious consequences for many developing countries.

The basic question here is how does development affect population growth?

Among the major issues relating to this question are the following:

1- Will developing countries be capable of improving the levels of living for their people with the current and anticipated levels of population growth? To what extent does rapid population increase the difficulty to provide essential social services, housing, transport, and security?

2- How will the developing countries be able to absorb the vast increases in their labor forces over the coming decades?

3- What are the implications of higher population growth rates among the poor developing countries?

4- Given the anticipated population growth, will developing countries be able to extend the coverage and improve the quality of their health and educational systems so that everyone can at least have the chance to secure adequate health care and a basic education?

5- To what extent are low levels of living are important factors in limiting the freedom of parents to choose a desired family size? Is there a relationship between poverty and family size?

Throughout this book we will use the following terms:

- **Environmental Quality**: Refers to the state of the natural environment and the quality of the environment.
- **Emissions**: The portion of production or consumption residuals that are placed in the environment.
- **Recycling**: The process of returning some or all of the production or consumption residuals to be used again in production or consumption.
- **Ambient Quality**: Refers to the surrounding environment or the quantity of pollutants in the environment.
- **Residuals**: Material that is left over after something has been produced. Materials and energy left after the

product has been produced are production residuals. Consumption residuals are what is left over after consumers have finished using the products that contained or otherwise used these materials.

- **Pollution**: Pollution is something that happens only when the ambient quality of the environment has been degraded enough to cause some damage.
- **Damages**: The negative impacts produced by environmental pollution on people.

1- Nature and The Economy:

At any point in time nature can be described by a series of variables specifying the **quantitative** and **qualitative** status of the system. The quantitative variables consist of stock variables (e.g., acres of forest, tons of marine biomass) and flow variables (e.g., energy striking the surface of the earth, wind speed), while the qualitative variables describe important features of the resources (e.g., parts per million of air pollution, salinity and temperature of water) at particular points of time. Biological and physical laws describe how these variables are transformed from one time to another.

A fruitful way of thinking about the nature resource system and its relationship to human welfare is to think of

it as a **stock of natural capital** which, in conjunction with other types of inputs, yields useful **goods and services**. The word "**capital**" has been used historically in economics to refer to a stock of human-produced artifacts, such as tools, machines, and buildings [1]. The concept of "**natural capital**" is useful because it combines the notion of nature-provided inputs with the idea that their quantity and quality can be affected by human actions.

Natural capital in conjunction with other inputs (human capital, artificial capital), produces a wide variety of goods and services. We can discuss these under two titels, as depicted in Figure (1): The arrow labeled (a) depicts the flow of natural resource products and services into an economy. Natural resource economics is the study of this flow using the analytical tools of economics. We must think of this broadly, as including both traditional extractive uses and the services provided by natural resource preservation. The arrow labeled (b) represents the flow of materials and energy residuals back into the natural world. This flow is the main subject of **environmental economics**.

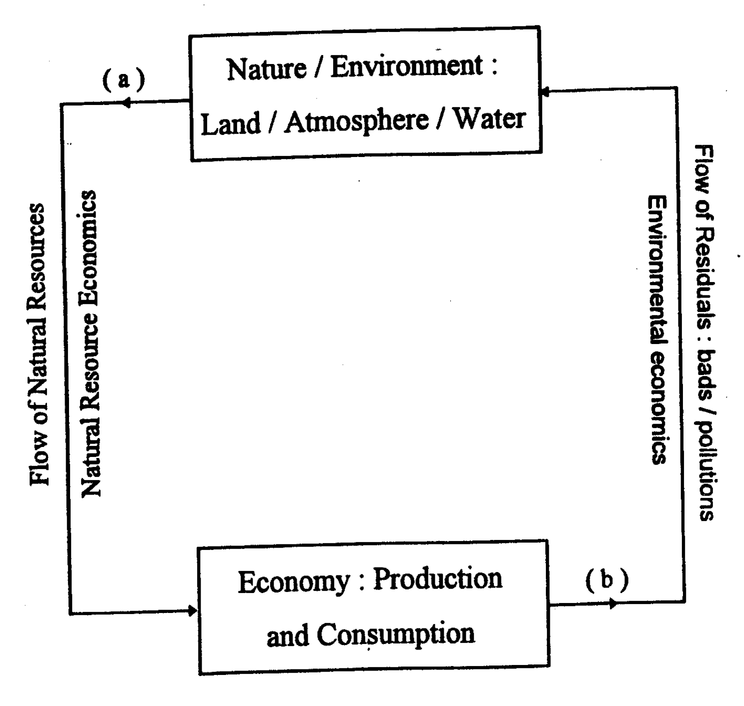
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[1] There are other recognized types of capital: **working capital**, the financial assets that permit the continuity of production and consumption, and **human capital**, the capacities and capabilities of human beings.

Which particular parts of the nature world have value depend on the characteristics of the society/economy in question. At any point in time an economic system will contain a variety of technological capabilities (e.g., different modes of production, distribution, and communication), economic, legal, and regulatory institutions (e.g., private business firm, a court system, commercial law, public agencies), and an important array of demographic factors (e.g., tastes and preferences, population sizes, skill levels, educational institutions). It is these technological, institutional, and demographic facts that make natural resources out of arbitrary elements of nature. One-hundred years ago petroleum was not a natural resource, nor was bauxite or uranium. Sixty years ago, water resources as the provider of recreational services were almost unknown. In recent years biological diversity has become an important natural resource. One hundred years from now some feature of the natural world that is currently unknown may have great social value and may be, in other words, a valuable natural resource.

Figure (1)

Nature and The Economy



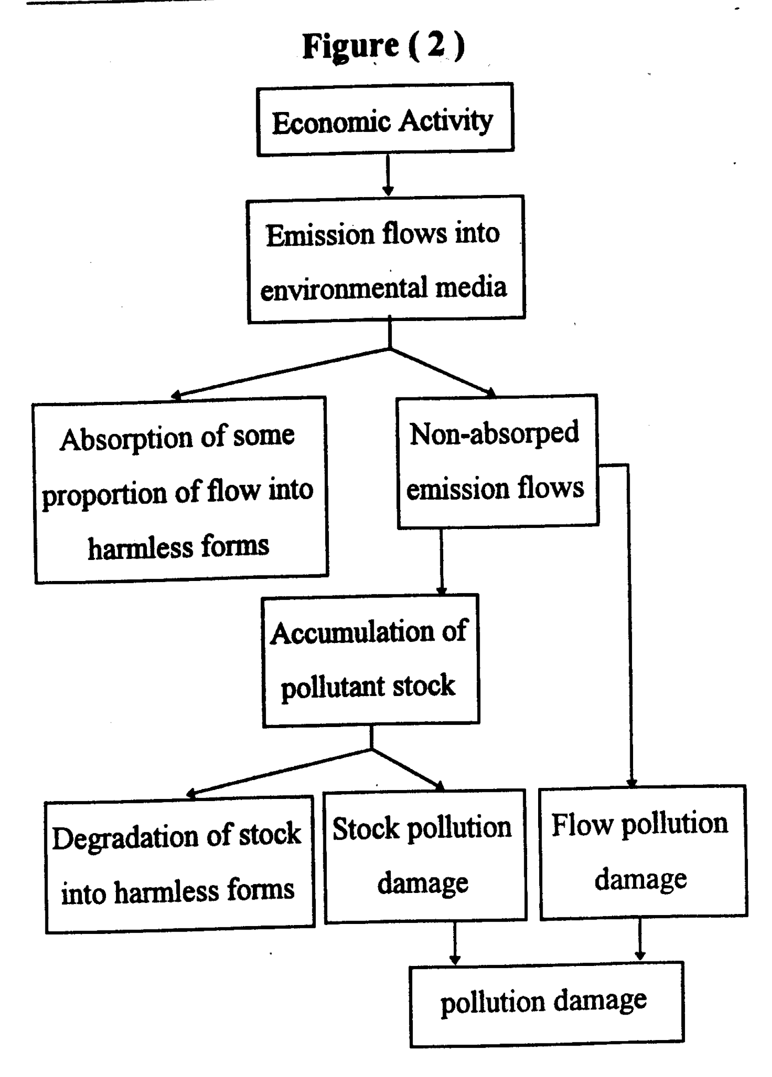
The return flow labeled (b) in the diagram highlights services being provided by nature in the form of a "sink" for the reception of wastes. Some of these wastes may be rendered more moderate through changes that are produced by the **assimilative capacity** of the environment. Some may accumulate and produce various types of nega-

tive impacts on human welfare and the health of the ecosystems comprising the natural world.

There is clearly a close relationship between natural resource economics and environmental economics. The laws of physics assure us that what is taken in by the economy, in terms of material and energy, must eventually come out. So the decisions undertaken in the context of flow (a) will have a lot to do with the problems that have to be addressed under flow (b). That is problems of resource depletion are related to problems of pollution.

Natural resources have been critical for human welfare since people first started to walk the earth several million years ago. And conflicts over resource use have no doubt been a permanent part of this long history. In this book we take an analytical perspective on problems of natural resource use, applying somewhat formal methods and principles of social rationality to issues that engender great contention and conflict in the real world. We should be familiar with some of the main terminology that this history has produced.

Figure (2)



See : Roger Perman, Yue ma , James, mc Gilvray (1996) Natural Resource & Environmental Economics : longman London , p. 198.

Of course the primary concept is natural resource **conservation**. Today we may say that conservation is the idea of using natural resources at a rate that is, in some sense, **socially** optimal. Of course, what is optimal for one person or group is not the same as what is correct for another, but the term does seemingly connote a course of action that finds an appropriate balance among diverse motives and avoids action that leads to waste and excessive damage.

One fault line that continues to run through public discussion is that between resource development and resource preservation. Development refers to actions that transform natural resources to a greater or lesser extent, presumably with the intent of increasing their contribution to the welfare of human beings. Preservation, on the other hand, connotes putting resources aside in a state of nonuse or in a state such that whatever use is allowed basically maintains the original status of the resource.

2- The Range of Natural Resource Services:

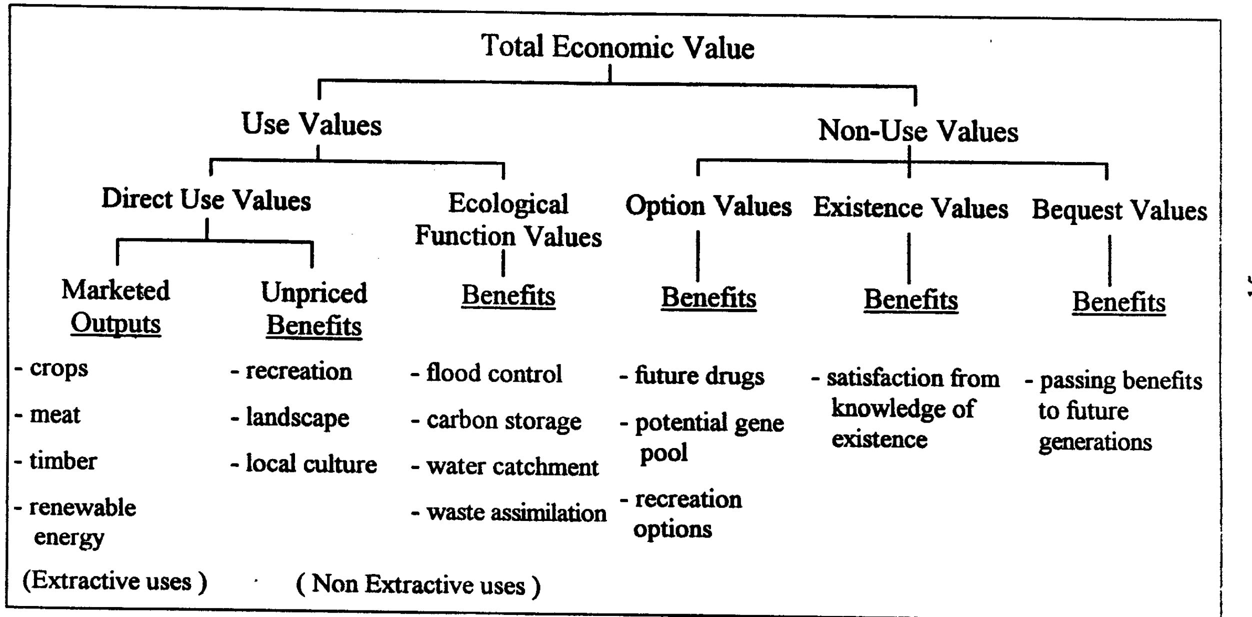
A minimal classification of natural resources would perhaps be : land resources, water resources, and air resources. But we need to move well beyond this delineation if we are to get more complete understanding of the num-

ber and variety of goods and services that nature provides. As a first step in this direction we distinguish between **use values** and **nonuse values**. Use value implies that attributes of nature are being utilized in some sense. This sense may be the classic one, such as when water is used to irrigate crops, which are then harvested and consumed. The sense of use may not involve traditional consumption. White-water rafting and bird watching are activities that use resources in a different sense.

Nonuse values, on the other hand, are values expressed by human beings simply for the **existence** of natural resources. Existence may be related to prospects for future use, called **option value**, or the desire to leave a healthy ecosystem to future generations, called **bequest value**. People may not be using a resource at present, but may prefer actions that will ensure that the resource is available in the future, should they or future generations wish to utilize it later; in other words, it is worth something to preserve the option. But true existence values, not linked to present or possible future use, also exist. They may of course be harder to assess and measure in particular cases, but they are nonetheless real and relevant to the full set of incentives that motivate human decisions.

Figure (3)

The Elements of Total Economic Value



The use value are broken down into **extractive** and **nonextractive** resources. Extractive resources are those subject to some process of physical removal from their natural surrounding and perhaps physical transformation during their use. Classic cases include the mining of ores of various types, and the harvesting of timber and its conversion to building materials. Commercial fishing, and much recreational fishing and hunting, are also extractive. It is common to use the term **natural resource products** (or commodities) to refer to quantities of physical resources that have been removed from nature and made available for use.

Nonextractive resources are those that yield valuable services without being removed from their natural setting. The classic case of a nonextractive resource-based recreation, such as backpacking and river rafting. Many resources produce both extractive products and nonextractive services. Forests may produce both timber and backpacking. Water can be used for municipal and industrial water supplies and for boating.

Table (1)

Classification of Natural Resources Use Values

Natural resource	Natural resource products and services	
	Extractive	Nonextractive
Minerals	Nonfuel (bauxite) Fuel (coal)	Geologica services (weathering)
Forests	Forest products (timber)	Recreation (backpacking) Ecosystem protection (flood control, CO_2 sequestration)
Land	Fertility	Space, scenic values
Plants	Food and fiber (agricultural crops, wild food crops) Biodiversity products (medicinal plants)	
Terrestrial animals	Food and fiber (farm animals, wild game) Biodiversity products (genetic variability)	Recreational services (bird watching, ecotourism)
Fisheries	Food (saltwater and freshwater fish)	Recreational services (recreational fishing, whale watching)
Water	Municipal and industrial supplies, irrigation	Recreation (boating)
Meteorological services	Energy sources (geothermal)	Energy sources (solar) Global radiation balances Radio spectrum Natural disasters

Another important nonextractive resource service is **ecosystem protection**. One part of a resource system provides support and protection for other parts. Wetlands, for example, are usually integral parts of wider hydraulic systems, so their protection is important in providing protection for water resources that are subject to direct extraction, such as groundwater aquifers. Forests often provide important services in flood control and the regulation of water quality. Land and water resources in coastal areas provide important services in terms of mitigation storm damage.

3- Measuring Stocks of Resources:

There are several other ways of distinguishing among types of natural resource goods and services. In order to discuss them, however, we will adopt a slightly more formal approach. The material that follows in this section will give us a chance to start thinking in ways that are somewhat more formal and abstract, but that preserve the essence of the resource situations we will want to study.

Natural resource management decisions are complex because they involve connections and trade-offs between the present and the future. The connections stem from the characteristics of the resource itself, such as its biology or chemistry, and the way they are impacted by human use.

Consider a situation in which there are just two time periods, period 0 and period 1. In effect period 0 could stand for today and period 1 for some time in the future, but to keep it simple think of period 0 as this year and period 1 as next year.

The basic structure of a general resource use and charge problem can now be set up in the following way. Suppose that there is a certain quantity of a resource available at the beginning of period 0. During that period the resource is "used" in some amount. It is easiest to think of "use" in this case as extraction in the traditional sense, But we also interpret it other ways. The other thing that may happen during the first period is some amount of replenishment or growth of the resource, the amount of which depends on the type of resource involved. All these factors contribute to the quantity of the resource available in period 1 .

We can express the basic relationship as follows:

Amount of resource available in period 1 (S_1)	=	Amount of resource available in period 0 (S_0)	-	Amount of the resource used in period 0 (Q_0)	+	Increment to the resource in period 0 (S_1)

or

$$S_1 = S_0 - Q_0 + \Delta S$$

The critical term is ΔS, representing the added increment of the resource that becomes available during period 0 [1]. By interpreting ΔS in different ways, we can use the basic expression to describe many different types of resources.

Nonrenewable Resources:

The most straightforward application of the general expression would appear to be a **Nonrenewable resource**. For a **known deposit** of such a resource, we have $\Delta s = 0$; that is, there is no replenishment or increment of the resource. This being the case, the basic accounting expression becomes $S_1 = S_0 - Q_0$; the quantity available in the next period is the quantity that was available at the beginning of the present period minus the quantity used in this period. The classic example is a mineral deposit containing a given quantity of material. It is true that very long-run geological processes may be creating new deposits, but in terms of the time spans that are relevant to generations of human beings, total quantities are effectively fixed in amount.

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[1] The symbol Δ is often used to denote the change in a variable of interest.

A resource in one circumstance may be renewable; in another circumstance it may not be. Groundwater is held in underground geological formations, or aquifers. In this case, ΔS is the **recharge quantity**, the quantity that flows into the formation during a year. In some cases ΔS is essentially zero, making that aquifer a nonrenewable resource. In other cases ΔS > 0, making it a renewable resource.

The basic character of nonrenewable resource changes if we move from considering a single deposit to considering **all known deposits**. Over a period of time, **exploration and development** can add to the quantity of the known stock. In this case ΔS is the quantity added to existing stocks through discovery and development. In fact this makes the situation quite complex because "new" deposits come in a variety of forms. For example, a deposit can new in the sense of recent geological discovery, or it may be "new" in the sense that we have a new technology capable of making use of it, as compared to last year when it was geologically known but essentially beyond our reach.

What this tells us is that the distinction between renewable and nonrenewable resources is only partly a physical one. It is also partly an economic one. The deci-

sion to put more effort into resource exploration is an economic one; it uses resources and has certain potentials in terms of benefits. Resource development, based on human actions, can convert cases that seemingly involve nonrenewable resources into cases of renewable resources.

Recyclable Resources:

Certain nonrenewable resources may be **recyclable**. A portion of the resource used in period 0 can be recycled back to add to the available supply in period 1. Here the basic expression may be rewritten as:

$$S_1 = S_0 - Q_0 + \alpha\, Q_0$$

where α is a percentage indicating the proportion of the first year's use that is returned via recycling. Here two basic decisions are to be made, that utilization rate Q_0 and the recycling ratio α.

Renewable Resources:

A **renewable Resources** is one that replenishes itself in some fashion. In this case $\Delta S > 0$, so the quantities available in period 1 are affected by the replenishment process. This may be a biological process, as for example in the case of fisheries or timber. For a forest, the amount of wood (in, e.g., cubic feet) in year 1 is what existed at

ity. Usage of a natural resource is reversible if it is possible that $S_1 > S_0$. By definition, utitization of a nonrenewable resource is irreversible, at least as long as we are talking about a particular deposit. Most renewable resources are reversible; if extraction is lowered sufficiently, the natural replenishment will cause the stock to increase, at least up to some biological maximum. But many renewable resources, especially biological resources, may have **thresholds** that, once past, render the resource irreversibly changed. The classic case is a population of wildlife in which the number of adults falls below a level sufficient to support reproduction greater than mortality, and hence evolves irreversibly toward extinction. More complex cases occur, for example, where characteristics of species diversity change in an ecosystem sufficiently to set in motion forces that bring about permanent changes in many structural and functional features of that ecosystem.

4- The Materials Balance Principle:

Concern with issues relating to resource use and the environment has not been exclusively (or even mainly) the subject of economic analysis, of course. Whilst the developments referred to above were taking place in the field of economics, attention was being given to environmental is-

sues in the natural sciences. In this section, we identify a number of the developments that had significant implications for the subsequent evolution of environmental economics.

We shall begin with the materials balance principle. The materials balance principle concerns identities that must hold between physical flows in any closed system, given the laws of thermodynamics.

A simple statement of this principle, which will suffice for our present purpose, is that the mass of residuals flows into environment from all forms of activity in the system equals the mass of resource flows from the environment. In figure (2 a), the materials balance principle is portrayed in its most simple form. In this representation, environment-economy interactions are shown as taking place, without any intermediation, between the environment itself and a final consumption sector. In this case, the material balance principle states that, provided no net accumulation of stock of goods takes place in the consumption sector, the mass of inputs from the environment into consumption must equal the mass of residual discharges from the consumption sector to the environment.

the beginning, minus that which was harvested during period 0, plus the biological growth increment of the timber that was not harvested. The size of the growth increment will be related to the size of the population and also other features of the ecosystem, such as climate.

Most biological growth processes involve **accumulation** to some degree; the resource growth adds to the resource stock. Certain types of renewable resources are nonaccumulating. Consider a free-flowing river, for example. Each year a certain (no doubt fluctuating) amount of water comes down the river; this is a meteorological and geographical fact of life. But it flows by a given point and then is gone. Thus the annual replenishment does not add to any preexisting quantity. In this case our basic relationship changes to the following:

$$S_1 = \Delta S$$

The amount of the resource available in period 1 now does not depend on the rate of use during period 0.

Of course if somebody were to build a reservoir on the river, the situation would change. Now the incoming flow would augment whatever was left in the reservoir from the previous year, changing a nonaccumulating resource into an accumulating one, at least to some degree.

Another example of a nonaccumulating renewable resource is the incoming stream of solar energy that strikes the earth each year. The stream itself is nonaccumulating, though of course all the biological processes it makes possible on earth represent accumulating phenomena.

This accounting expression can be applied to land resources, but it will look different according to the exact way we define the resource, If we write the formula for the total land area in a given geographical region, such as a town, the expression is simply $S_1 = S_0$. In other words, the total area is fixed and unchanging (barring political changes in town boundaries). But if we define our resource of interest as, for example, land devoted to a particular use, such as housing developments, wetlands, or land in agriculture, it would look like

$$S_1 = S_0 - Q_0 + \Delta S$$

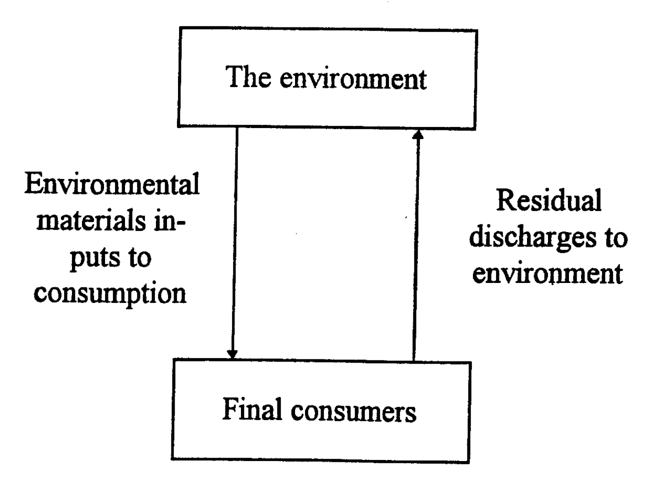
where Q_0 is the amount of acreage taken out of that use during the year (e.g., number of acres devoted to new housing development) and ΔS is the amount of land put back into that use (e.g., wetlands restored, if our S variable of interest is acreage of wetlands).

An important feature of some natural resources is reversibility, expressed in terms of either quantity or qual-

The representation given in figure (2 b) is, of course, grossly over-simplified. This shows, again in a very simplified manner, the physical relationships implied by the materials balance principle, taking into account the presence of intermediate production and recycling processes.

Figure (2 a)

The materials Balance Principle



Commencing from the top of the diagram, we see that basic primary inputs (ores, liquids and gases) are taken from the environment and converted into useful products (basic fuel, food and raw materials) by 'environmental' firms. The outputs of these processes become inputs into subsequent production processes (shown as a product flow

to non-environmental firms) or to households directly. Households also receive final products from environmental firms sector.

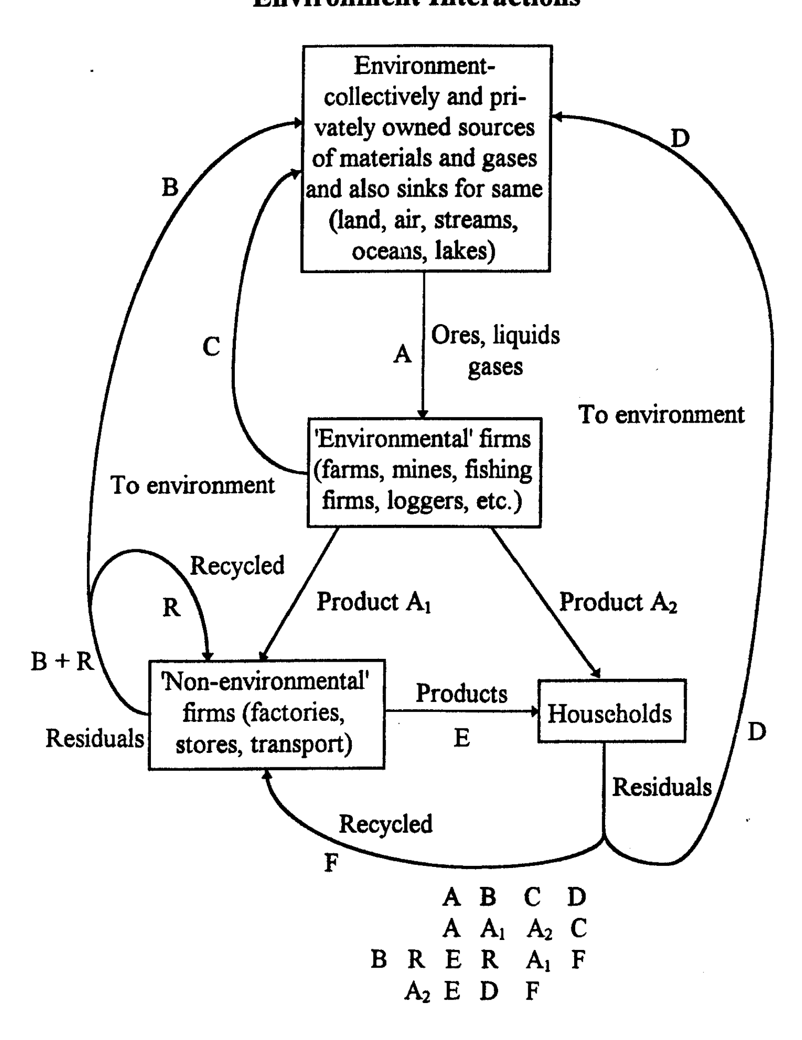
The essence of the materials balance principle is the identity between the mass materials flow from the environment (the flow A) and the mass of residual material discharge flow to the environment (flows B + C + D). In terms of mass, we have

$$A = B + C + D$$

Notice that several other sets of identities are suggested by figure (2 b). Each of the four sectors shown by rectangular boxes receives an equal mass of inputs to the mass of its outputs. So we have the following four mass identities:

Figure (2 b)

A Materials Balance Model of Economy-Environment Interactions



A B C D
A A1 A2 C
B R E R A1 F
A2 E D F

The environment : $A = B + C + D$ as above

Environmental firms : $A = A_1 + A_2 + C$

Non-environmental firms : $B + R + E = R + A_1 + F$

Households : $A_2 + E = D + F$

Several interesting and important insights can be derived from this model. Firstly, in a closed economy (no materials flows to or from the outside) in which no net stock accumulation takes place (i.e. the stocks of buildings, plant, other capital and consumer durables do not change in magnitude), the mass of residuals into the environment (B + C + D) must be equal to the mass of fuels, foods and raw materials extracted from the environment and oxygen taken from the atmosphere (flow A). This merely restates the fundamental identity stated above, but a corollary of this is that the mass of residual discharges is larger than the mass involved in basic materials production (the difference being accounted for by the oxygen consumed).

Secondly, the materials balance principle shows that 'treatment' of residuals from economic activity does not reduce their mass, it merely alters their form. This is a consequence of the law of conservation of mass: matter cannot be created or destroyed, although its form can be altered. Nevertheless, whilst it is important to be clear that waste

treatment does not 'get rid of' waste, it is nevertheless true that the form in which residual discharge enter the environment can have a considerable impact on the damages that discharge flows create. Waste management is useful, therefore, not because it reduces the mass of waste but because it alters residuals from a less to a more benign form.

Thirdly, the extent of recycling is important. To see how, look again at the identity

$$B + R + E = R + A_1 + F$$

For any fixed magnitude of final output, E, if the amount of recycling of household residuals F can be increased, then the quantity of inputs into final production A1 can be decreased. This in turn implies that less primary extraction of environmental resources A need take place. This is of fundamental importance; the total amount of material throughput in the system (the magnitude A) can be decreased for any given level of production and consumption if the efficiency of materials utilization is increased through recycling processes. As many ecologists argue that the ultimate determinant of environmental damage is the level of materials throughput in the system, a very strong case for recycling is apparent. But note that there are limits to how far recycling should be undertaken. It is not a costless activity. Recycling of materials uses materials too; re-

cycling should not (even from a purely ecological perspective) be pushed beyond the point where the mass of inputs used in recycling exceeds the reduction in material throughputs that it allows.

The importance of the materials balance principle resides in the fact that it provides a coherent framework in which an economic analysis of resource use and its implications for environment can be placed. It draws one's attention to the long-term implications of economic activity, by focusing on the stock-flow relationships implied by that behavior, and its importance follows from the discipline it imposes in thinking about stock and flow relationships. Typical analyses of the optimal depletion of an exhaustible resource, for example, pay no attention to the residual flows into the environment as an extracted resource is consumed.

Section I

Environmental Economics

Chapter 2

The Economics of Environmental Quality

Environmental economics focuses on the connection between environmental quality and the economic behavior of individuals and groups of people. There is the fundamental question of how the economic system shapes economic incentives in ways that lead to environmental degradation as well as improvement.

There are major problems in measuring the benefits and costs of environmental quality changes, especially intangible ones. There is a set of complicated macroeconomic questions, for example, the connection between economic growth and environmental impacts and the feed back effects of environmental laws on growth, and there are the critical issues of designing environmental policies that are both effective and equitable. The strength of environmental economics lies in the fact that it is analytical and deals with concepts such as: efficiency, trade-off, costs, and benefits. We have to get hard scientific results on how people value environmental quality and how they are hurt when this quality is degraded.

Environmental Economics is the application of the principles of economics to the study of how environmental resources are managed. Economics is divided into micro-economics: the study of the behavior of individuals and small groups, and macroeconomics: the study of the economic performance of economies as a whole. Environmental Economics draws from both sides, although more from microeconomics than from macroeconomics. It focuses primarily on how and why people make decisions that have consequences for the natural environment. It is concerned also with how economic institutions and policies can be changed to bring these environmental impacts more into balance with human desires and the needs of the ecosystem itself.

Environmental Economics has a major role to play in the design of public policies for environmental quality improvement. There are an enormous range and variety of public programs and policies devoted to environmental matters, at all levels of government, local, state, regional, and international, they vary greatly in their efficiency and effectiveness.

1- The Economics of Environmental Quality:

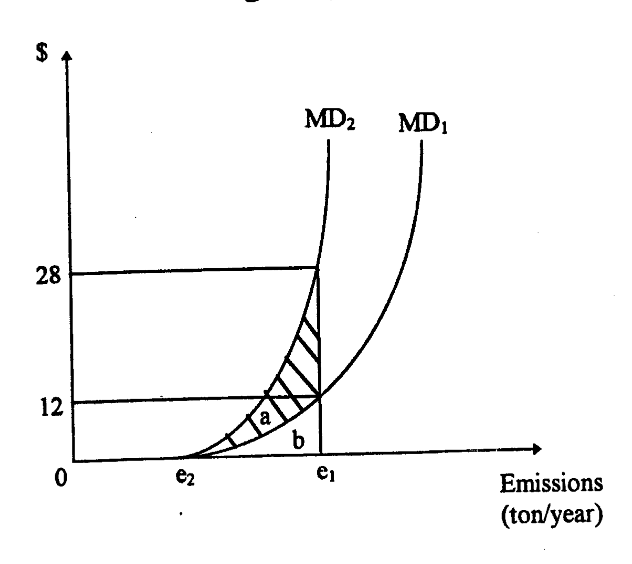
Environmental issue includes a number of closely related issues, such as: How to divide up the task of meeting environmental quality goals. If we have many polluters, how should we seek to allocate among them an overall reduction in emissions? Another issue is the question of how the benefits and costs of environmental programs are distributed across society and whether this distribution is appropriate? Before developing a simple policy model, it needs to be stressed that effective public policy depends on good information on how economic and environmental system actually work. The essence of the model consists of a simple trade-off situation that characterizes all pollution-control activities. On the one hand, reducing emissions reduces the damages that people suffer from environmental pollution; on the other hand, reducing emissions takes resources that could have been used in some other way. The abatement costs and the damages costs are the two sides of the basic pollution-control trade-off.

By damages we mean all the negative impacts that users of the environment experience as a result of the degradation of that environment. These negative impacts are of many types and will vary from one environmental asset to another.

Damage Functions:

In general, the greater the pollution, the greater the damages it produces. To describe the relationship between pollution and damage, we will use the idea of a damage function. Damage function shows the relationship between the quality of a residual and the damage that residual causes. A marginal damage function shows the change in damages stemming from a unit change in emissions.

Figure (1)



The previous figure shows two marginal damage curves. When the emission level is at the point (e_1), marginal damage are $12. In case of marginal damage function

MD_1 and point e_1 total damages are equal to the monetary amount expressed by the triangular area (b). For any given level of emissions, marginal damages are higher for MD_2 than for MD_1. At emission level e1, for example, a small increase in effluent would increase damages by $12 if the marginal damage function were MD_1, but it would increase damage by $28 if it were MD_2. Remember that any damage function shows the impacts of emitting a particular effluent in a particular time and place, so one possible explanation might be that MD_2 refers to a situation in which many people are affected by a pollutant such as a large urban area, whereas MD_1 refers to a more sparsely rural area (fewer people, smaller damage). One major factor that moves damage functions upward is an increase in the number of people exposed to a particular pollutant.

Another possibility that might offer an explanation of why one marginal damage function lies above another is that although they apply to the same group of people, they refer to different time periods. Damage results from ambient pollution, whereas what we have on the horizontal axis is quantity of emissions. The functioning of the environment is what connects these two factors. Suppose the pollutant in question is some sort of material emitted into the air by industrial firms located near an urban area and that

the damage functions refer to impacts felt by people living in that area. Marginal damage function MD_2 might occur when there is a temperature inversion that traps the pollutant over the city and produces relatively high ambient concentrations. MD_1 would be the damage function, however, when normal wind patterns prevail so that most of the effluent is blown downwind and out of the area. Thus, the same emission levels at two different times could yield substantially different damage levels due to the workings of the natural environment.

Because MD_2 is above MD_1, it corresponds not only to higher marginal damages but also to higher total damages. At emission level e_1, total damages are equal to area b when the damage function is MD_1, but to area (a + b) when the damage function is MD_2.

Abatement Costs:

Abatement Costs are the costs of reducing the quantity of residuals being emitted into environment, or of lowering ambient concentrations. Think of the pulp mill located upstream. In its normal course of operation it produces a large quantity of organic wastes. On the assumption that it has free access to the river, the cheapest way to get rid of these wastes is simply to pump them into the

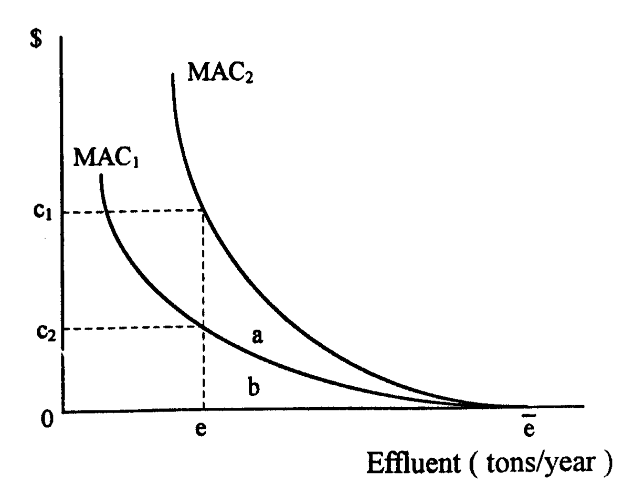
river, but the firm normally has technological and managerial means to reduce these emissions. The costs of engaging in these activities are called "abatement costs" because they are the costs of abating, or reducing, the quantity of residuals put into the river. By spending resources on this activity, the pulp mill can abate its emissions; in general, the greater the abatement, the greater the cost.

To investigate more deeply the concept of marginal abatement cost, consider Figure (2), which shows two marginal abatement cost curves. For the moment we focus on the higher one, labeled MAC_2. It begins at an effluent level marked e, the uncontrolled emission level. From there it slopes upward to the left. beginning at the uncontrolled level, the first units of emission reduction can be achieved with a relatively low marginal cost. Think again of the pulp mill, this first small decrease might be obtained with the addition of a modest settling pond, but as emission levels are reduced further the marginal cost of achieving additional reductions increases. For example, to get a 30-40 percent reduction, the pulp mill may have to invest in new technology that is more efficient in terms of water use. A 60-70 percent reduction in effluent might require substantial new treatment technology in addition to all the steps taken previously, whereas a 90-95 percent reduction might

take very costlv equipment for recycling virtually all of the production residuals produced in the plant. Thus, the larger the reduction in emissions, the greater the marginal costs of producing further reductions. This yields a marginal abatement cost function that gets steeper in slope as emissions are reduced.

Figure (2)

Anatomy of a Marginal Abatement Cost Curve



Of course, there is an upper limit on these abatement costs. The extreme option for a single plant or pollution source is to stop operations, thereby achieving a zero level of emissions. The costs of doing this depend on circumstances. If the source is just one small plant within a large

industry consisting of many such plants, the costs of closing it down need not to be that great. In fact it may have very little impact on, say, the price to consumers of whatever is being produced (e.g., paper in the pulp mill), although the local impact on jobs and community welfare may be substantial. But if we are talking about the marginal abatement costs for an enter industry electric power production in the midwestern United States, for example the "shutdown" option, as a way of achieving zero emissions, would have enormous costs.

The marginal abatement cost function can express **actual** marginal costs of a source or group of sources or the lowest possible marginal abatement costs. Actual costs, of course, are determined by the technologies and procedures that firms have adopted in the past to reduce emissions. These could have been affected by a variety of factors, including managerial shortsightedness or public pollution control regulations. To use the model for studying questions of social efficiency and cost effectiveness, however, we don't want actual costs but the lowest possible abatement costs. In this case, we have to assume that sources have adopted whatever technological and managerial means are available to achieve emission reductions at

the lowest possible costs. We have to assume, in other words, that sources are acting in a **cost-effective** manner.

As with any marginal graph, we can depict not only marginal but also total values. If emissions are currently at e tons per year, the value on the vertical axis shows the marginal cost of achieving one more unit of emission reduction. The area under the marginal abatement cost curve, between its origin at point $\bar{e}$ and any particular emission level, is equal to the **total costs** of abating emissions to that level. For example, with the curve labeled MAC_2, the total abatement cost of achieving an emission level of e tons per year is equal to the area under the curve between $\bar{e}$ and e, the area (a + b) ; remember we are reading the graph from right to left.

Consider now the other marginal abatement cost curve shown in Figure (2), labeled MAC_1. Its main feature is that it lies below MAC_2, meaning that it corresponds to a situation where the marginal abatement costs for any level of emissions are lower than those of MAC_2. At $\bar{e}$ tons per year of emissions, for example, the marginal costs of abating an extra ton are only c_2 in the case of MAC_1, which are substantially lower than the marginal abatement costs of MAC_2 at this point. What could account for the difference? Let us assume that we are dealing with the same pollutant

in each case. One possibility is that these apply to different sources; for example, a plant that was built many years ago and another that was built more recently and uses different production technology. The newer plant lends itself to less costly emissions reduction.

Another possibility is that MAC_1 and MAC_2 relate to the same pollutant and the same source, but at different times. The lower one represents the situation after a new pollution-control technology has been developed, whereas the upper one applies before the change. Technological change, in other words, results in a lowering of the marginal abatement cost curve for a given pollutant. It possible to represent graphically the annual cost that this source would save assuming the emission rate is e before and after the change. Before the firm adopted the new technology, its total abatement cost of achieving effluent level e was equal to (a + b) per year, whereas after the change the total abatement costs are b per year. The annual cost savings from the technological change are thus a. This type of analysis will be important when we examine different types of pollution-control policies because one of the criteria we will want to use to evaluate these policies is how much cost-saving incentive they offer to firms to engage in re-

search and development to produce new pollution-control technologies.

The Socially Efficient level of Emissions:

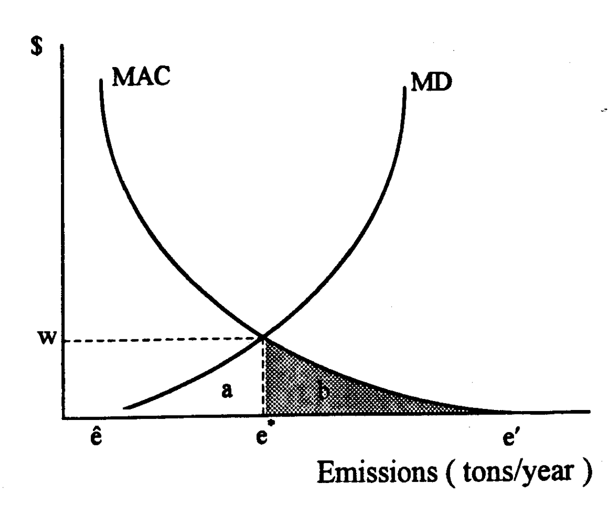
Having considered separately the marginal damage function and marginal abatement cost function related to a particular pollutant being released at particular place and time, it is now time to bring these two relationships together. This we do in Figure (3), which depicts a set conventionally shaped marginal damage and marginal abatement cost curves labeled, respectively, MD and MAC. Marginal damages have a threshold at emission level $\hat{e}$, whereas the uncontrolled emission level is e'.

The "efficient" level of emissions is defined as that level at which marginal damages are equal to marginal abatement costs. What is the justification for this? Note the trade-off that is inherent in the pollution phenomenon: higher emissions expose society, or some part of it, to greater costs stemming from environmental damages. Lower emissions involve society in greater costs in the form of resources devoted to abatement activities. The efficient level of emissions is thus the level at which these two types of costs exactly offset one another; that is, where marginal abatement costs equal marginal damage costs.

This is emissions level e^* in Figure (3). Marginal damages and marginal abatement costs are equal to each other and to the value w at this level of emissions.

Figure (3)

The Efficient level of Emissions



We also can look at this outcome in terms of total values because we know that the totals are the areas under the marginal curves. Thus, the triangular area marked a (bounded by points ê and e^* and the marginal damage function) depicts the total damages existing when emissions are level e^*, whereas the triangular area b shows the total abatement costs at this level of emissions. The sum of these two areas (a + b) is a measure of the total social

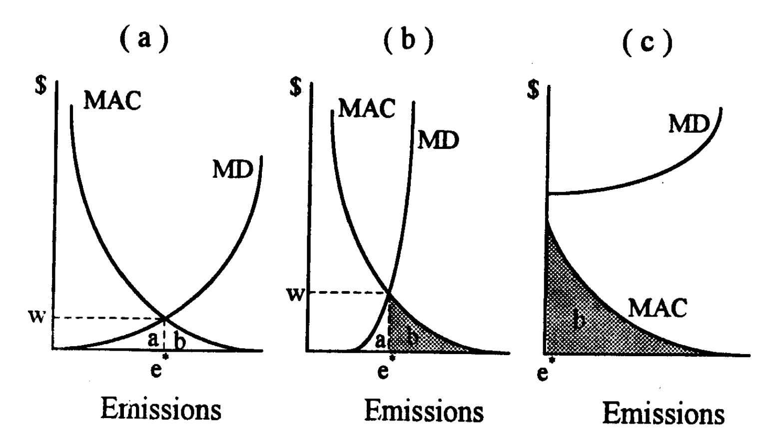
costs from e^* tons per year of this particular pollutant. The point e^* is the unique point at which this sum is minimized. Note that the size of area a need not equal the size of area b.

You might get the impression, on the basis of where point e^* is located on the x-axis, that this analysis has led us to the conclusion that the "efficient" level of emissions is always one that involves a relatively large quantity of emissions and substantial environmental damages. This is not the case. What we are developing, rather, is a conceptual way of looking at a trade-off. In the real world every pollution problem is different. This analysis gives us a generalized way of framing the problem that obviously has to be adapted to the specifics of any particular case of environmental pollution. Figure (4), for example, depicts three different situations that might characterize particular environmental pollutants. In each case e^* depicts the efficient level of emissions and w shows marginal damages and marginal abatement costs at that quantity of emissions. Panel (a) shows a pollutant for which e^* is well to the right of zero (of course, since the horizontal axis has no units, it's not clear exactly what "well to the right" actually means here). marginal damages at this point are quite small; so are total damages and abatement costs, as shown by the small size of the triangles corresponding to these

values. The reason is that this is a pollutant where both marginal abatement costs and marginal damages increase at first only very slowly.

Figure (4)

Efficient Emission Levels for Different Pollution



Panel (b) shows a situation where the marginal abatement function rises very rapidly from the beginning. In this case e^* is well to the right of zero, and w lies well above what was in first diagram (assuming the vertical aces of these diagrams all have the same scale). Note, however, that at e^* total abatement costs are substantially higher than total damages, as is indicated by the relative sizes of the triangles that measure these total values (a and b). What this emphasizes is that it is not the equality of to-

tal abatement costs and total damages that defines the efficient level of effluent, but the equality of the **marginal abatement costs and marginal damages**.

In panel (c) of Figure (4) the efficient level of emissions is zero. There is no point of intersection of the two functions in the graph; area a does not even appear on the graph. The only way we could conceivably get them to intersect is if we could somehow extend them to the left of the vertical axis, but this would imply that emissions could actually be negative, which is an oddity that we will avoid. What makes $e^* = 0$ is that the marginal damage function doesn't begin at zero, but rather well up on the y-axis, implying that even the first small amount of this pollutant placed in the environmental causes great damage (perhaps this diagram applies to some extremely toxic material). Relative to this the marginal costs of abatement are low, giving an efficient emission level of zero.

Changes in the Efficient Level of Emissions:

The real world is a dynamic place, and this is especially true of environmental pollution control. For our purposes this implies, for example, that the level of emissions that was efficient last year, or last decade, is not necessarily the level that is efficient today or that is likely to be in

the future. When any of the factors that lie behind the marginal damage and marginal abatement cost functions change, the functions themselves will shift and e^*, the efficient level of emissions, also will change.

Before taking a look at this we need to remind ourselves of what we are doing. Remember the distinction made earlier between positive and normative economics, between the **economics of what is** and the **economics of what ought to be**. The idea of the efficient level of emissions comes firmly under normative economics, under the idea of what ought to be. We are presenting emissions level e^*, the level that balances abatement costs and damage costs, as a desirable target for public policy. Do not get this confused with the actual level of emissions. If the world worked so that the actual level of emissions was always equal to, or close to, efficient level, we presumably would have no need to worry about intervening with environmental policy of one type or another. Of course it does not, which is why we must turn to public policy.

Figure (5) shows several ways in which e^* might change when underlying factors change. Panel (a) shows the results of a shift upward in the marginal damage function, from MD_1 to MD_2. One of the ways this could happen is through population growth. MD_1 might apply to a mu-

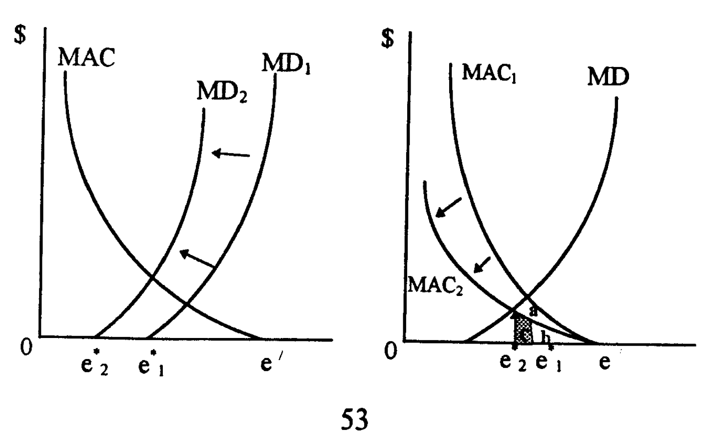
nicipality in 1980 and MD_2 to the same municipality in 2000 after its population has grown. More people means that a given amount of effluent will cause more damage. This leads to a conclusion that is intuitively straightforward: The efficient level of emissions drops from e^*_1 to e^*_2. With a higher marginal damage function, the logic of the efficiency trade-off would lead us to devote more resources to pollution control.

Panel (b) of Figure (5) shows the case of a shift in the marginal abatement cost function, from MAC_1 to MAC_2. What could have caused this? The most obvious, perhaps, is a change in the technology of pollution control. As stressed earlier, abatement costs depend critically on the technology available for reducing effluent streams: treatment technology, recycling technology, alternative fuel technology, and so forth. New techniques normally arise because resources, talents, and energy have been devoted to research and development. So the shift downward in marginal abatement costs depicted in Figure (5) might be the result of the development of new treatment or recycling technologies that make it less costly to reduce the effluent stream of this particular pollutant. It should not be too surprising that this leads to a reduction in the efficient level of emissions, as indicated by the change from e^*_1 to e^*_2. We

might note that this could lead to either an increase or a decrease in the total cost of abating emissions. Before the change, total abatement costs were an amount equal to the area (a + b) ; that is, the area under MAC_1 between the uncontrolled level e' and the amount e^*_1. After the change, total abatement costs are equal to area (b + c), and the question of whether total abatement costs at the efficient level of emissions have increased or decreased hinges on the relative sizes of the two areas a and c. This in turn depends on the shapes of the curves and the extent to which the marginal abatement cost curve has shifted ; the more it has shifted, the more likely it is that the efficient level of total abatement costs after the change will exceed the costs before the change.

Figure (5)

Changes in e^*, The Efficient Level of Emissions



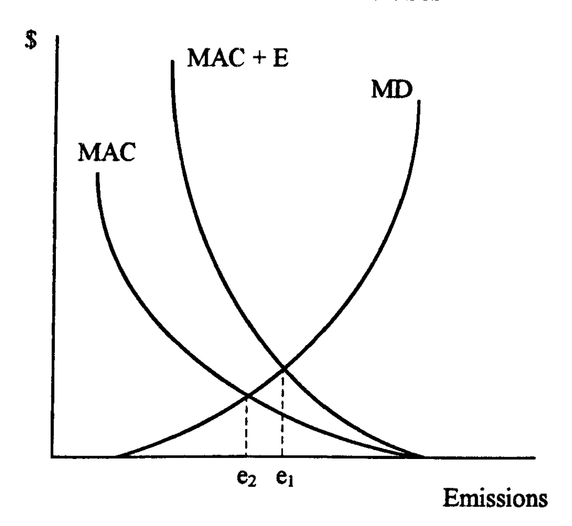
Enforcement Costs:

So far the analysis has considered only the private costs of reducing emissions, but emission reductions do not happen unless resources are devoted to enforcement. To include all sources of cost we need to add **enforcement costs** to the analysis. Some of these are private, such as added record keeping by polluters, but the bulk are public costs related to various regulatory aspects of the enforcement process.

Figure (9) shows a simple model of pollution control with enforcement costs added. To the normal marginal abatement cost function has been added the marginal costs of enforcement, giving a total marginal cost function labeled MAC + E. The vertical distance between the two marginal cost curves equals marginal enforcement costs. The assumption drawn into the graph is that marginal enforcement costs, the added costs of enforcement that it takes to get emissions reduced by a unit, increase as emissions decrease. In other words, the more polluters cut back emissions, the more costly it is to enforce further cutbacks.

Figure (6)

Enforcement Costs



In effect, the addition of enforcement costs moves the efficient level of emissions to the right of where it would be if they were zero. This shows the vital importance of having good enforcement technology because lower marginal enforcement costs would move MAC + E closer to MAC, decreasing the efficient emission level. In fact, **technical change in enforcement** has exactly the same efficient on the efficient level of emissions as technical change in emissions abatement.

The Equimarginal Principle Applied To Emission Reductions :

Before going on we will take a last, very explicit look at the equimarginal principle. In the present context, the application of the equimarginal principle says the following: If there are **multiple sources** of a particular type of pollutant with **differing marginal abatement costs**, and if it is desired to reduce aggregate emissions at the **least possible cost** (or alternatively, get the greatest reduction in emissions for a given cost), then emissions from the various sources must be reduced in accordance with the **equimarginal principle**.

To illustrate this, look at the numbers in Table (2). This shows explicitly the marginal abatement costs of each of two firms emitting a particular residual into the environment. If neither source makes any effort to control emissions, they will each emit 12 tons/week. If Plant A reduces its emissions by 1 ton, to 11 tons/week, it will cost $ 1,000/week; if it reduces effluent further to 10 tons/week, its abatement costs will increase by $ 2,000/week, and so on. Note that the marginal abatement cost relationships of the two sources are different: that of Source B increases faster than that of Source A.

Table (1)

The Equimarginal Principle

Emissions (tons/week)	Marginal abatement costs ($1,000/week)	
	Source A	Source B
12	0	0
11	1	2
10	2	4
9	3	6
8	4	10
7	5	14
6	6	20
5	8	25
4	10	31
3	14	38
2	24	58
1	38	94
0	70	160

Suppose that initially each plant is emitting at the uncontrolled level; total emissions would then be 24 tons/week. Now assume that we want to reduce overall emissions to half the present level, or a total of 12 tons/week. One way to do this would be to have **equiproportionate** cutbacks. Because we want a total reduction of 50 percent, each

source is required to reduce by 50 percent. If Source A were cut 50 percent to 6 tons/week, its marginal abatement costs at this level would be $ 6,000/week, whereas at this level of emissions the marginal abatement costs of Source B would be $ 20,000/week. Total abatement costs of the 12-ton total can be found by adding up the marginal abatement costs ; these are $ 21,000/week for Source A ($ 1,000 + $ 2,000 + $ 3,000 + $ 4,000 + $ 5,000 + $ 6,000) and $ 56,000/week for Source B ($ 2,000 + $ 4,000 + $ 6,000 + $ 10,000 + $ 14,000 + $ 20,000), or a grand total of $ 77,000/week.

The overall reduction to 12 tons/week, however, can be achieved with a substantially lower total cost. We know this because the equiproportionate reduction violates the equimarginal principle; marginal abatement costs are not equalized when each source reduces its effluent to 6 tons/week. What is required is different emission rates for the two sources, where, simultaneously, they will emit no more than 12 tons of effluent and have the same marginal abatement costs. This condition is satisfied if Source A emits 4 tons and Source B emits 8 tons. These rates add up to 12 tons total and give each source a marginal abatement cost of $10,000/week. Calculating total abatement costs at these emission levels gives $39,000/week for

Source A ($1,000 + $2,000 + $3,000 + $4,000 + $5,000 + $6,000 + $8,000 + $10,000) plus $22,000/week for Source B ($2,000 + $4,000 + $6,000 + $10,000) or a grand total of $61,000/week. By following the equimarginal principle, the desired reduction in total emissions has been obtained, but with a savings of $16,000/week over the case of an equiproportionate reduction.

Thus, we see that an emission reduction plan that follows the equimarginal rule gives emission reduction at minimum cost. Another way of saying this is that for any particular amount of money devoted to effluent reduction, the maximum quantitative reduction in total effluent can only be obtained by following the equimarginal principle. The importance of this principle cannot be overstated. When defining the efficient level of emissions, we were going on the assumption that we were working with the lowest possible marginal abatement cost function. The only way of achieving this is by controlling individual sources in accordance with the equimarginal rule. If we are designing public policy under the rule of equiproportionate reductions at the various sources, the marginal abatement cost function will be higher than it should be. One of the results of this is that the "efficient" emission level will be higher

than it should be, or, to say the same thing, we will seek smaller reductions in emissions than are socially efficient.

2- Economic Development and the Environment :

It is common to distinguish between economic growth and economic development. There is a simple, as well as a more complicated, way of distinguishing between these concepts. In simple terms, growth refers to increases in the aggregate level of output, whereas development means increases in per-capita output. Thus, a country could grow, but not develop, if its population growth exceeded its rate of economic growth. The more complicated way is to say that economic growth refers to increases in economic activity without and underlying change in the fundamental economic structure and institutions of a country, while development also includes a wider set of technological, institutional, and social transformations. Changes in such things as education, health, population, transportation infrastructure, and legal institutions are all part of the development process. This should alert us to the fact that when talking about environmental issues in developing countries, we will usually be talking about situations where

the social and technological issues can be very different from that in industrialized countries.

In speaking of these issues, there is the tendency to divide the world into just two parts: developed and developing, or "first" world and "third" world. Of course, any brief classification such as this is an enormous oversimplification of the real world. At the very least we should think not of a simple categorization such as this but of a continuum, running from the poorest to the richest, or along any other dimension of interest. The countries of the world are spread along that continuum, although not necessarily evenly. It's also true that national aggregates can tend to obscure some important development problems within particular countries. many countries that look reasonably good on the basis of national macro-data have pockets of poverty and underdevelopment that would be sufficient to put these regions in the less developed ranks if national political boundaries were drawn differently.

Economy and Environment:

Whereas the concern about environmental problems has been of more recent origin, issues related to economic growth in the less-developed world have been uppermost for many years; indeed, historically they have been a defin-

ing focus of this group of countries. This emphasis on economic development will continue as they strive to close the economic gap with the developed economies. What needs to be examined, therefore, is the relationship between economic development and environmental quality.

A Static View:

Probably the most frequently mentioned viewpoint on these matters is that developing countries simply cannot afford high level of environmental quality. According to this view, the situation of these countries, in comparison to developed economies, can be pictured by the production possibilities curves (PPCs) of Figure (7). Marketed output refers to the conventional types of goods and services produced and distributed through economic markets. The PPC labeled A is for a typical developed country, while B refers to a developing nation. Because of past resource exploitation, or population pressures, or less sophisticated technology, B lies entirely within A. Thus, to achieve higher levels of marketed income, which it must if it is to develop, it must be willing to put up with lower levels of environmental quality. For example, for the developing country to reach a level of marketed output of c_1, it must trade off environmental quality back to the level e_2. The developed country, because of the factors mentioned previously, can

have c_1 of marketed output with a much higher level of environmental quality e_1 instead of only e_2. As one economist put it:

the poorer countries of the world confront tragic choices. They cannot afford drinking water standards as high as those the industrial countries that would.

Chapter 3

The Best Environmental Quality

Damage to the environment is clearly undesirable. Why not stop it? While this might seem to be an attractive objective, in practice it is not realistic. As we saw before, environmental impacts are pervasive. All activities require energy and materials, and usually both, and so they emit waste energy and produce residuals. These emissions into the environment must have some sort of impact on it. If we take the view that all environmental impacts should be stopped then we would have to stop all forms of production. Rather then. We want to stop those environmental impacts that are in some sense harmful. This requires a judgment as to which impacts are regarded as harmful and which are not.

The definition of an optimal environmental quality in economic terms is illustrated in Figure (1). Consider a production process which is the cause of an external cost. In Figure (1) the line CBP represents the marginal private benefit (MPB) to the producer. This is the profit which is made from the last unit of production, i.e. marginal revenue less marginal cost, and we assume that this represents the

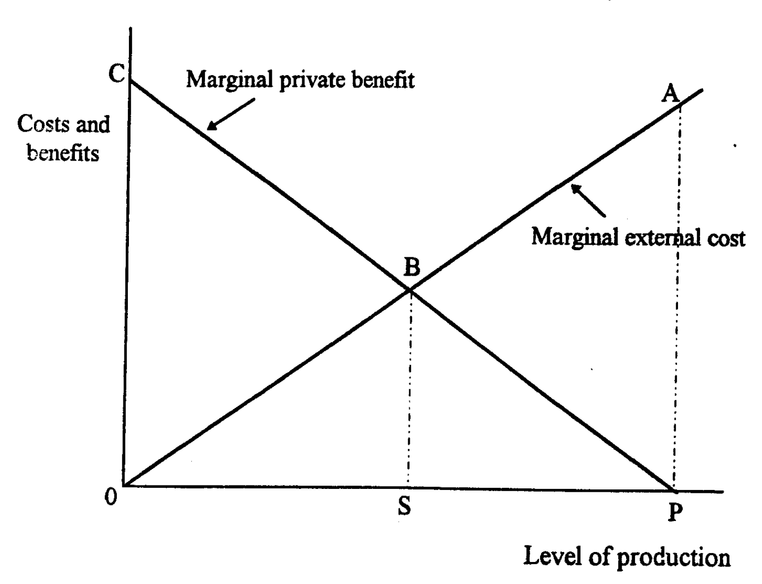
value of the production to society. As the level of production increases it is assumed that the marginal benefit decreases to zero at point P, where marginal revenue equals marginal cost. At this point the producer will maximize his total profit and hence this is the level of production which he would choose. However, production causes an external cost, which is represented by the marginal external cost (MEC) line OBA. Similarly, this indicates the external cost caused by the last unit of production. It is assumed that there is only one method of production available, so that the relationship between the level of production and the level of the external cost is fixed. In this case the marginal external cost is assumed to increase with the level of production.

At P, the marginal private benefit is zero, while the marginal external cost is substantial. While the last unit of production generates no gain to the producer, it does cause significant environmental damage. There is then a net gain to be had from preventing its production. As can be see from Figure (1) there is an advantage to be made from preventing all production in excess of S. In this region (between S and P), for each unit of production, the marginal external cost is greater than the marginal private benefit. However, for production levels below S, the reverse is the case. The marginal private benefit exceeds the

marginal external cost. Therefore, taking account of all costs, the optimal level of production is at S. In moving from P to S, there is a gain in terms of the total reduction of external cost equal to the area ABSP, while there is a loss of BSP in terms of the producer's profit. There is thus a net gain equal to BAP.

Figure (1)

Optimal Environmental Quality



Note that some pollution remains at S. It would be possible to stop pollution, but only at the expense of stopping all production. In cutting back from S to 0 there

would be a gain from reduced external cost equal to OBS but this would be less than the loss to the producer of OCBS. There would be a net loss of OCB. We accept that economic activity causes some changes to the environment and that this imposes some costs. We only wish to restrict these costs where the value of the environmental improvement is greater than the costs of restricting the productive activity. This is the efficient solution. It simply recognizes that costs arising from environmental change should be accounted for and treated like any other cost of production.

There are, of course very many difficulties in translating this simple principle into a calculation of the optimal environmental quality in practice. It would be necessary first to trace all of the impacts through the environment in order to establish all of the possible ways which people may be affected, either now or in the future. We would then have to establish what costs they impose. We will examine the methods which might be adopted in attempting this later, but it will be no surprise to learn that it is not easy. Obviously, the complexity of estimating environmental relationships and of calculating costs are major reasons why environmental impacts are often disregarded in the first place.

Alternative Views of an Optimal Environmental Quality:

One modification to the simple equalization of marginal external cost with marginal private benefit has been suggested by David Pearce. Some forms of pollution have the potential to influence the assimilative capacity of the environment, i.e. its ability to absorb and render harmless waste products. Some possible implications of this are illustrated in Figure (2).

As before, the horizontal axis represents the level of production which generates some waste which is deposited into the environment. The top part of the figure shows W the amount of waste rising in line with production and A which represents a constant assimilative capacity of the environment. Where the amount of waste is below the assimilative capacity, it is degraded in the environment and does not cause any environmental damage. Beyond this level, E, environmental damage is caused. The bottom part of Figure (2) repeats Figure (1), except that no external cost is caused in the region where the volume of waste produced is less than the assimilative capacity of the environment. Beyond this, the marginal external cost rises as before. Thus, as before, P represents the level of produc-

tion which would maximize the producer's profit and S the apparent socially optimal level.

Figure (2)

Optimal Environment and Assimilative Capacity

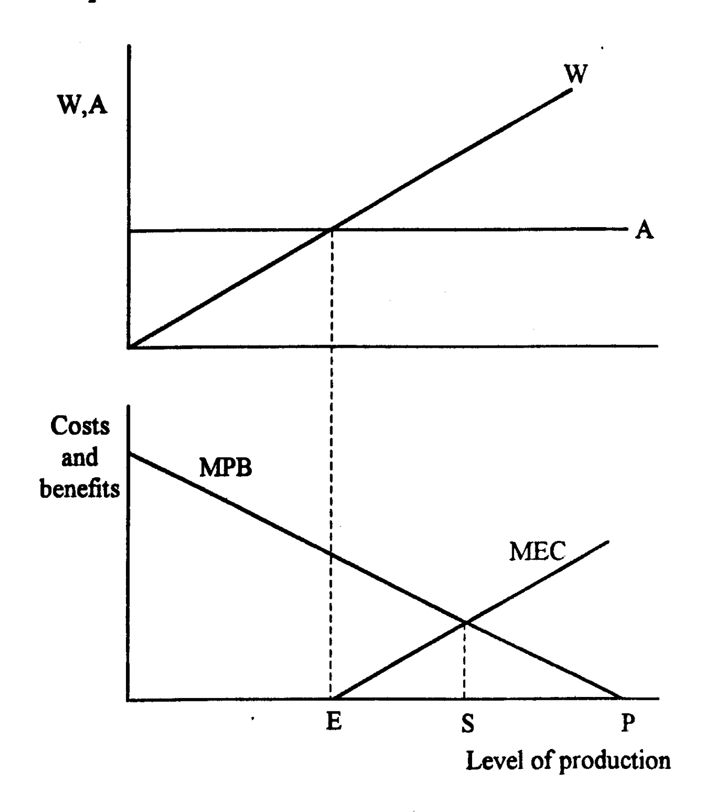
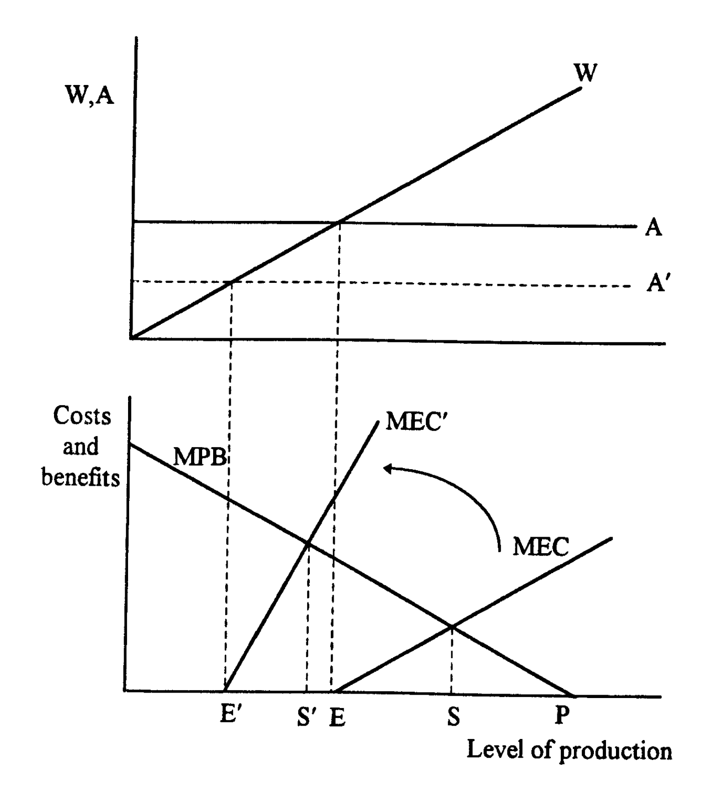


Figure (3)

Optimal Environment and Changing Environmental Capacity



However, suppose that if the level of waste exceeds the assimilative capacity, this reduces the capacity of the environment to degrade waste products, i.e. reduces the

assimilative capacity itself. This would be the consequence of operating at S, and the implications of this possibility are as shown in Figure (3).

Operation at S, leads to a reduction of the assimilative capacity from A to A′. Hence the origin of the MEC shifts back to E′ and there is a new 'socially optimal' level of production at S′ But it should be obvious that this situation is also unstable. The level of waste remains above the assimilative capacity of the environment and so the capacity would again be reduced. And so on. Depending upon the ecological characteristics of the environment, the process could continue until any production causes external costs in excess of the private benefit, so that the optimal level is zero.

It is apparent that this process could have been avoided if production had been restricted to E in the first place. Pearce refers to this as the 'ecologically stable output'. But this level represents a zero level of pollution, in the sense that no external cost is being caused. There is still some environmental impact. In other terms of Figure (1) , it would appear that production is being unduly restricted.

It might be argued that a complete calculation of the external costs would take account of the dynamic consequences elaborated here, such that the social optimum would coincide with the ecologically stable level of output. In order to achieve this, the MEC would have to rise vertically from E. This may be possible, but it is more probable that the information available will not be sufficient to enable the full consequences to be identified. It will usually be the case that the effects are long term and, in terms of environmental processes, remote from the location at which the waste is emitted. We do not have full knowledge of the relevant relationships in the environment and so there will be at least uncertainty as to what the long-term effects may be.

The interpretation of this analysis may be at differing levels. The discussion might relate to the deposition of some waste product by one producer into a single lake. The maximum extent of the damage might then just be the destruction of the ecology of the lake. Even here, though, it should be noted that the inevitable interrelationships in the environment mean that further consequences are likely to occur. On the other hand, the analysis may be seen as representing aggregate production at a global level, in which the damage to the environment

which arises could represent the loss of the capacity of the planet to support life. A vertically rising MEC can then be seen to be appropriate.

Which of the two situations describing an 'optimal' level of pollution is appropriate? In some cases, the full consequences of an environmental impact are fully evident and limited. For instance, the construction of an ugly building within an attractive landscape is undesirable, but its consequences may not extend beyond the local visual impact. Crowding on beaches is a nuisance to those affected but has little wider importance. On the other hand, the release of CFCs causing damage to the ozone layer, or emission of significant quantities of radioactive materials, are likely to have widespread and potentially disastrous consequences. It is notable that the two examples in the latter category and most similar examples are characterized by high degrees of uncertainty. Thus the distinction between the two situations is rarely clear and is always based on judgments as to what the full consequences are and as to their importance.

Pollution and Economic Policy:

It has been argued that all economic activity involves the production of waste residuals, in either energy

or mass forms. Fundamental physical principles, moreover, imply that it is not possible, through economic processes, to convert these residuals completely into useful forms. The perfect recycling of wastes is impossible. We know, also, that waste residuals can become damaging pollutants if their flows into environmental sinks exceed the carrying capacity of these environmental media. What role should government take with regard to environmental pollution. Indeed, should it have any role at all, other than just creating and sustaining the conditions for competitive market behavior?

We begin attempt to answer these questions by outlining in the next section some insights developed by Ronald Coase, the most important of which draws attention to the possibility that bargaining between affected parties can lead to efficient solutions to externality problems. Coase's work points to the importance of property rights and transactions cost in determining the extent to which bargaining will take place. If circumstances are favorable for the existence of bargaining, external effects will often be efficient dealt with by private bargaining. Under these conditions, no public intervention is necessary to secure an efficient allocation of resources. This is a very powerful insight, and should lead one to be wary of asser-

tions that government corrective action is necessary whenever external effects are present in economic activity However, for a very large class of external effects, the circumstances required for bargaining solutions to be applicable will not be met. Market allocations will then be inefficient, and gains may be possible through government intervention. The source of these potential efficiency gains, and insights into how one can design policy instruments to secure them, can be found using the economic theory of externalities.

After briefly reviewing the concept of an economically efficient level of pollution, attention turns to what this implies for an economically efficient pollution abatement programme. The main emphasis of our arguments throughout this chapter is on the efficiency properties of various pollution abatement programmes. However, it is always important to remember that efficiency is not the only relevant criterion when assessing alternative choices, nor necessarily the most important one. So it may not be always desirable to construct policy in terms of a full economic efficiency criterion. Human Communities appear to be unwilling to allow all policy targets to be decided using economic criteria, and may instead press for some to be chosen using other criteria. This often seems to be the case

where health issues are under consideration ; many people think it wrong for the size of the health care budget to be decided on economic grounds. When environmental matters are being discussed, similar views are often expressed, and it is common to find criticisms of economists for attempting to 'reduce everything to monetary considerations' and ignoring our responsibilities towards non-humans. So whilst the economist is inclined to stress the usefulness of decision frameworks based around the idea of economic efficiency, there is no ground for believing that policy targets either should be set or actually will be set in this way.

A second reason why targets may not be set using a full economic efficiency criterion is that this may not be possible because of limitations in the information available to decision makers. Suppose that government knows the costs of controlling a particular kind of pollutant, but does not know the pollution damage costs ; it will then not be possible to identify an economically efficient pollution level. In that case, pollution targets must be chosen using some other criterion. However, once a pollution control target has been selected, whether on the basis of an economic or a non-economic criterion, economic reasoning still has a role to contribute in designing a programme to achieve that target. In particular, we might wish to adopt

thc criterion that any target should be achieved at least cost. This is known as the cost-efficiency criterion, and is discussed at length in a following section. As you will see, the criterion of cost-efficiency is not an alternative criterion to that of economic efficient - rather, it is a weaker condition. An economically efficient pollution control programme achieves a particular target - the economically efficient pollution level - at the minimum overall cost to society. A cost-effective programme merely attains some target, but not necessarily the best one, at minimum cost to society.

Pollution is viewed within the framework of the economic theory of externalities. It follows from such a perspective that if a polluting externality can be internalized, market behavior should lead to an efficient outcome. This suggests that we should investigate how externalities can be internalized in a market economy. As we have seen, Coase's work shows one way in which externalities can be internalized, through private bargains. We show in the fourth and fifth sections that some forms of economic policy instrument, including pollution taxes and pollution abatement subsidies, also have this property, and so offer the prospect of being used to obtain an efficient allocation of resources where unregulated markets would fail to do so.

We have already noted that government may have incomplete information about either the costs or the benefits of various types and levels of intervention. It turns out to be the case that incomplete information has important implications for the design and choice of policy instruments. The type of instrument which is "best" for achieving some particular goal will depend upon the form which uncertainly takes.

Our preliminary analysis of pollution control programmes is set in the context of a particular class of pollutants - those which we define to be uniformly mixing flow pollutants. The meaning of this phrase will become clear as you read through the chapter. In the seventh section of this chapter, we turn our attention to flow pollutants that do not mix uniformly, and so have localized or regional effects that can vary with the time of the emission. Then we investigate pollution control programmes for stock pollutants.

Although it is desirable that, other things being equal, an economic instrument should be efficient, it is important to realize that different instruments can have very different implications for the way in which the gains and costs of policy intervention are distributed. The political

choice of instrument is likely to be influenced by distributional issues at least as by efficiency criteria.

Whilst we argue in this chapter that markets sometimes fail to deliver efficient outcomes, there is no guarantee that government invention will not be subject to efficiency losses also. It would be quite wrong to assume that a potential efficiency gain will inevitably be achieved by government intervention. In some circumstances, the efficiency losses of intervention might exceed those arising from the market failure which prompts that intervention, and so public sector involvement may not be warranted.

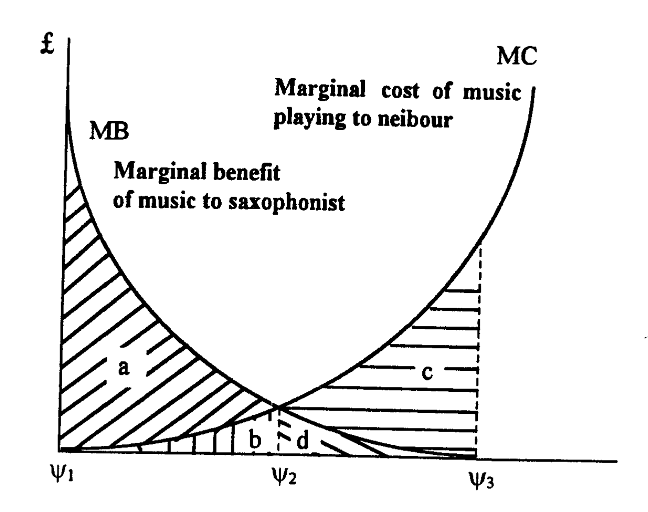
Bargaining and the Work of Ronald Coase:

It is argued that one situation in which environmental "problems" tend to arise is where property rights are ill-defined or do not exist. Let us now investigate this claim. To fix ideas, consider two people living as neighbours, one who plays a saxophone for his own enjoyment, the other who finds the sax noise disturbing. Figure (4) represents these two effects of the music, the curve MB denoting the marginal benefits to the musician derived from playing his instrument, and MC denoting the marginal cost of sax playing to disturbed neighbour. The horizontal axis is

measured in units of noise, labeled ψ, to indicate that we treat this case as an example of a pollution externality.

Figure (4)

The Bargaining Solution to an Externality



If the musician behaved without any regard for his neighbour, and were not subject to any external control, he would maximize his private benefit at the output ψ_3, where all additional benefits to him from sax playing have been exhausted. This would clearly not be an efficient outcome, however. The efficient solution is found at output level ψ_2. How might such an outcome be achieved?

One method is via bargaining between the affected parties. Starting from the noise level ψ_3, a mutually beneficial bargain (a Pareto improvement) is possible. If a bargain were struck such that the musician reduced his noise output to the level ψ_2, the gains to the disturbed neighbour would be shown by the areas c + d. The loss to the musician is represented by the area d. Thus provided the neighbour compensated the musician by some payment greater than d, but less than c + d, both individuals would be in a superior position than they were initially. A Pareto improvement would have taken place, and an efficient outcome would have been achieved. Potentially inefficient outcomes can be avoided if the affected parties can bargain with one another to establish mutually beneficial outcomes. Putting this argument another way, inefficiencies create the basis for mutually beneficial bargains, which may, depending on the circumstances, take place.

So far, we have deliberately remained silent about how rights to emit noise pollution (or equivalently, right to use the medium in which sounds can travel) are allocated ; we have said nothing about property rights. As we show shortly, a bargaining solution is only likely to take place if enforceable property rights exist. But does the manner in which these rights are distributed matter in any way? Con-

tinuing our example, let us focus on two of the ways in which such rights could be distributed. Firstly, producers may be given unconstrained rights to produce noise (or to make use of the relevant environmental medium). Secondly, individuals may be granted the right to noise-free environments. In his article, Ronald Coase reached two conclusions. First, he argued that where bargaining is free to take place, and the costs of bargaining are negligible, efficient outcomes will be achieved through bargaining between affected parties. Second, he claimed that the same, efficient outcome will be attained irrespective of the way in which property rights are distributed. The manner in which property rights are distributed does matter, but only in determining the distribution of the net gains which arise from the bargain. They do not matter in terms of the final way in which real resources are allocated. This second result is commonly known as Coase's Theorem.

To see the basis for the Coase Theorem. look again at Figure (4). If property rights were vested in the producer of noise, the producer would have no legal liability for any noise he produced, and the pre-bargaining level of noise output would be ψ_3. However, for the reason we gave above, one would expect bargaining to take place between the affected parties, leading to the final outcome ψ_2. If, on

the other hand, legislators granted residents the right to a noise-free environment, the producer would not be entitled to generate any noise, and so the pre-bargaining pollution level would be ψ_1. However, the two parties are still confronted by the possibility of a mutually beneficial transaction. That transaction would take the form of the neighbour allowing the musician to produce ψ_2 without seeking redress through the courts. In return for this entitlement, the musician would compensate the neighbour by an amount greater than b but less than a + b in terms of the areas in Figure (4). You should convince yourself that such a deal would be of benefit to both persons.

Coase's first argument was that the likelihood of such a bargain taking place will be low unless enforceable property rights exist. Enforceability refers to the fact that the judicial system would impose punitive penalties on any individual infringing another's property right. A bargain can be thought of as a contract between individuals whereby the holder of property rights agrees to waive any claim for damages resulting from the other party, in exchange for some compensation. If enforceable property rights do not exist, contractors could renege on contracts after compensations have been paid without fear of redress. This is known as opportunistic recontracting. The

existence of property rights, and the existence of a legal system which guarantees the enforcement of contracts and of property rights, appear to be necessary conditions for bargaining solutions.

Coase's results are of immense importance. Firstly, they show that bargaining between affected parties may allow potentially inefficient outcomes to be avoided without the need for any government regulation. Self-interested behaviour may ensure that resources will be deployed efficiently, even where external or spillover effects take place. If bargaining solutions to externalities do in fact take place widely, or could easily do so, the proper scope for government intervention in the economy is greatly reduced. Secondly, the manner in which property rights are initially distributed has no effect as far as the efficient allocation of resources is concerned. If efficiency were the only thing that mattered, then this means that as long as property rights do exist, it is irrelevant how they are distributed. However, efficiency is not the only thing that "matters". If one believes that distributional issues deserve consideration, then the initial distribution of property rights is clearly relevant. As problem (1) demonstrates, the distribution of gains and benefits from bargaining will depend upon property rights distributions.

Section II

Natural Resource Economics

Chapter 4

Policies For Natural Resources

In this chapter we review some of the major types of policy alternatives that are available in a market economy to manage natural resource conservation and utilization. Our objections are: first, to understand that there are different types of natural resource policies and, second, to assess the applicability of these policies in different circumstances.

Types of Public Policies:

The policy problem refers to the question of how to bring about a state of affairs in which people's private behavior is also socially appropriate.

Incentive-Based Policies:

A- Property Rights Policies:

Many natural resource problems can be attributed to inadequate or inappropriate property rights governing access to the resources property rights must have several important characteristics if they are to lead to socially efficient resource use. They must be:

1- Complete.

2- Enforceable at reasonable cost.

3- Transferable.

4- Combined with a complete set of competitive markets.

1- ***Complete***: Property rights must not be limited in any way that would reduce the incentives of the owners to search out the ways that maximize their value. For purposes of protecting the public health, owners do not have the right to use their property in a way that would injure others.

2- ***Enforceable at reasonable cost***: By enforceable we refer to two things: 1- that would be trespassers can be excluded at reasonable cost, 2- that owners can be effectively enjoyed from using their property in ways that are illegal. Exclusion has two dimensions: technical and legal. The technical side is the physical means available for stopping trespassers. The legal side relates to whether boundaries are recognized by legal authorities. Both factors are important. In many cases natural resources have been essentially privatized by individuals or groups who take it upon themselves to exclude certain outsiders.

3- ***Transferable***: Many existing communities in developing countries have placed restrictions on selling land to nonresidents. The reasons for this are primarily social and political. If a community's land is the only productive asset it has.

4- ***The presence of markets***: For private property to lead to efficient resource use palters, markets must exist so that owners can capture the full value of the services produced by the resource in question. Only then can we be sure that resources will be devoted to the uses that maximize their social value. Property rights arrangements have efficiency implications, they also have important distribution , or equity.

B- Government-Sponsored Incentive Policies:

A government-sponsored incentive policy is one in which authorities try to shift the incentive aspects of a situation so that resource users will be motivated voluntarily to adjust their behavior in the direction of efficiency. These policies may be involve taxes or subsidies or a combination of the two.

1- Taxes:

We will take the following numerical example: Consider the data in the following table (1) which show the

costs and returns of a small calm fishery. The second column is catch per fishery, which tends to decline as fishers increase because more fishers create congestion and greater scarcity. The larger the number of fishers, the more the decline. The third column shows total catch. The last three columns show, respectively, costs per fisher (assumed the same for all fishers), total costs, net returns per fisher, and aggregate net returns (total revenue minus total costs).

Table (1)

Number of fishers	Catch per fisher Pounds	Total catch Pounds	Cost per fisher $	Total cost $	Net returns per fisher $	Aggregate net returns $
1	20	20	12	12	8	8
2	20	40	12	24	8	16
3	20	60	12	36	8	24
4	20	80	12	48	8	32
5	18	90	12	60	6	30
6	16	96	12	72	4	24
7	14	98	12	84	2	14
8	12	96	12	96	0	0
9	10	90	12	108	-2	-18
10	8	80	12	120	-4	-40

Suppose now that authorities charge $ 7 per day per fisher. This policy will change the financial incentives facing each fisher. From the stand point of the fishers, the cost

per fisher column now consists of $ 19 rather than $ 12. The equilibrium point occurs between 4 & 5 fishers where marginal cost = average value = 19. The tax in otherwords, has shifted the costs of the fishers, so that now, even with no direct control over entry, the number of fishers will stop at 4 (the socially efficient level). Return to the previous table, the net return column can now be divided as follows:

Table (2)

Number of fishers	Net returns		
	Total $	Tax receipts $	Net to fishers $
1	8	7	1
2	16	14	2
3	24	21	3
4	32	28	4
5	30	35	-5
6	24	42	-18
7	14	49	-35
8	0	56	-56
9	-18	63	-81
10	-40	70	-110

The tax approach is quite different from the property approach studied earlier. In the property rights approach the total rent shared by the 4 fishers would be $ 32. In the tax approach it would be $ 4 and the authorities would get the other $ 28. Such distributional consequences reduce the

political attractiveness of using taxes to achieve efficient resource utilization rates.

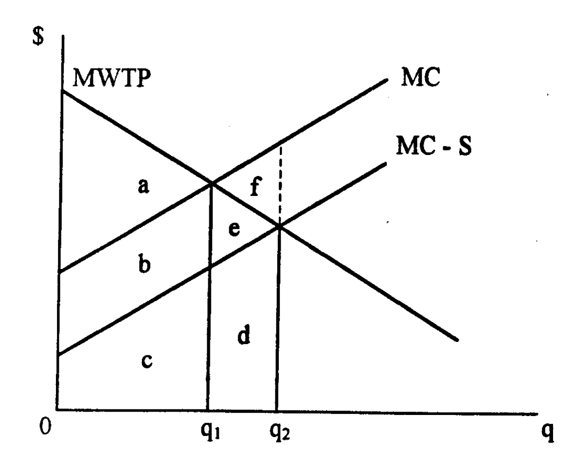
2- Subsidies:

Subsidy is a payment to individuals in return for their reduced use of the resource in question, the objective is to affect the rate at which the resource is used. Subsidies are usually have a redistribution objective to transfer income often from the general taxpayer to favored groups or sometimes to individuals.

The following graph illustrates the case of production which is subsidized. The real social marginal cost curve is MC while the subsidized marginal cost curve which determines the effective market supply curve is MC minus the subsidy (MC - S). The subsidy lowers the effective marginal cost curve. Thus, the market output will be at q_1 which is somewhat larger than the socially efficient output q_2. At q_2 the net social benefits would be (a + b + c) - (b + c) = a whereas at an output level q_1 net social benefits are (a + b + c + d + e) - (b + c + d + e + f) = a - f. Thus, the subsidy would produce a social gain equal to the area f. In effect society would gain simply because it moves to a position that is socially efficient from one that is not.

So why then don't governments end subsidies of this sort? The answer is that although there will be a gain to society, ending subsidies means ending the flow of redistributional income toward certain groups. Thus, it is in the interests of these groups to use the political process to pressure the subsidies.

Figure (1)



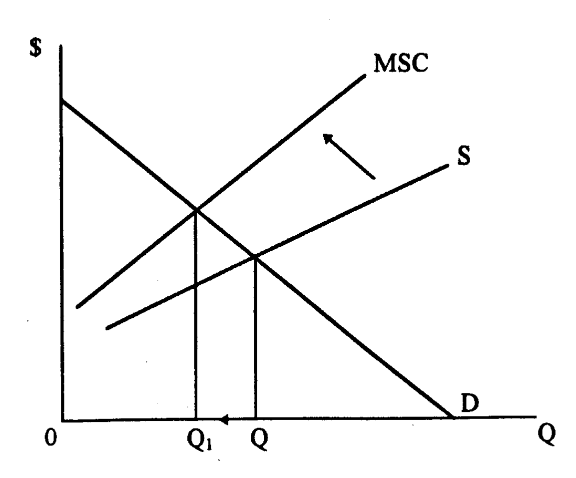
3- Direct Controls:

This approach is aimed to control natural resource use. Sometimes is called the Command-and-Control Approach.

The following figure shows the market demand (D) and supply (S) of a natural resource where the equilibrium

quantity is Q. Suppose that there are additional costs not being taken into account by the market suppliers, this will increase the cost and the new social cost function MSC will intersect with demand curve at a new equilibrium point where the new equilibrium quantity Q_1 is less than Q.

Figure (2)



Chapter 5

The Valuation of Natural Resources

In this chapter we will try to deal with certain principles of valuation of natural resources.

Measuring Benefits:

We first make some distractions among some types of benefits as follows:

1- Passive Natural Resource Values (Non Use Values):

Are involved when people place value on a resource independent of their actual use of the resource. Various motives have been suggested as the source of these values such as:

- Option Values: People may be willing to pay to preserve a resource.
- Existence Value: Willingness to pay to maintain the existence of resources even if there is no future utilization.
- Bequest and Gift Value: Willingness to pay to ensure that others, in both current and future generations will

enjoy a world in which the particular resources are present.

2- Direct Market Price Analysis:

Benefits obtained when people actually use the resources. Use values can be divided into those which are expressed through markets and non-market. When markets are involved, interactions among buyers and sellers establish prices and quantities of transactions which can often be analyzed to determine the willingness to pay of demanders and the marginal costs of suppliers. Market prices and quantities can be used to reveal these values in two ways. They can be used directly when be used indirectly when what is being traded is not the resource itself but another good or service that is closely associated with it.

Figure (1)

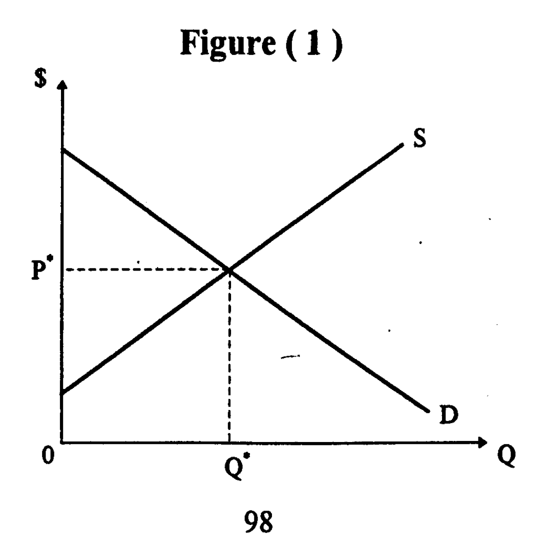
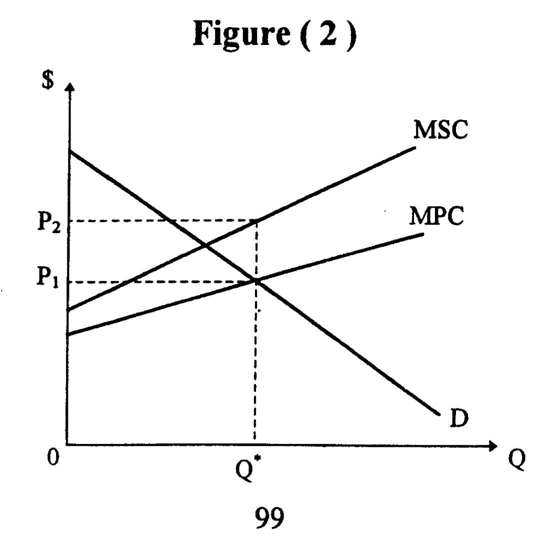


Figure (1) shows the standard supply and demand functions of a market. The price P^* is the one that brings the quantity supplied into balance with the quantity demanded. On the assumption that there are no externalities on either side of the market and that the market is competitive. This price is an accurate indicator of both marginal willingness to pay and marginal cost at the quantity Q^*.

When markets are present they provide a good indicator for estimating resource values because market participants are essentially revealing these values through their interactions.

When environmental externalities are involved, figure (2) presents the standard externality model.

Figure (2)



We will apply this case to the electricity market. D is the electricity demand curve, assumed to be an accurate representation of social marginal willingness to pay for electricity. MPC is the marginal private costs of producing electricity, and MSC is the marginal social cost of production. The difference is accounted as the external cost of electricity generation primarily air pollution. In the absence of property rights changes or government policy that causes these external effects to be priced, the private market supply curve for electricity will be MPC, and the market price and quantity of electricity will be respectively P_1 and P_2.

3- Indirect Market Price Analysis:

In many cases direct markets simply do not exist, where the nature of the resource is such that direct markets are difficult to organize (Air quality which is considered as strong public good).

In some cases activity in related markets can be studied to determine resource values. In such cases the value of the resource may be estimated indirectly by estimating price, quantity, and quality data of the associated good or service in the related market. As an example, consider the issue of open space preservation suburb. As sub-

urban development in many countries around the world has continued, more thinking is being given to preserving some acres in open space like parks, visual buffers, and areas of ecological value. The costs of preservation are the value of development that they foreclose. These costs are fairly easily measured. But how can we assess benefits?

Although there is no market where people buy and sell units of open space directly, there is a closely related market in which open space can be expected to have an impact; the suburban housing market. The market for new and used houses is very active throughout the country. The price of a house is affected by many factors: the characteristics of the house itself and those of the neighborhood in which it is located. We assume that buyers purchase houses having the most desirable set of characteristics given their income.

Another type of indirect market-price analysis is the travel-cost approach. This method takes advantage of the fact that people have to incur travel costs to visit the natural resource sites, the benefits people get from these resources depend in large part on the quantitative characteristics of these resources. Resource economists have developed techniques for reducing demand and benefit estimates

by using travel costs as proxies for the normal market prices that are used in market demand studies.

There are essentially two major components of travel costs: direct monetary costs and indirect monetary costs. These costs would be expected to be higher for people living farther from the visiting cities.

4- Non-market Techniques:

Resource economists have developed a special technique for estimating willingness to pay when direct or indirect market techniques are not available. It is called contingent valuation, and is a survey technique based on the straightforward idea that people's willingness can be determined by asking them directly. Contingent valuation (CV) studies have been done for a long list of natural and environmental resources.

The steps in a CV analysis are the following:

- Identification and description of the environmental quality characteristics to be evaluated.
- Identification of respondents to be approached including sampling procedures used to select respondents.
- Design and application of a survey questionnaire through personal, phone, or mail interviews.

- Analysis of results and aggregation of individual responses to estimate values for the groups affected by the environmental change.

Measuring Costs:

We switch now to the cost side of Benefit-Cost Analysis. All actions have cost consequences, whether this be costs of the obvious sort in classical natural resource extraction.

The results of a benefit-cost analysis can be affected equally by over-or underestimating costs as by over-or underestimating benefits.

Costs analysis can be done on many levels. Price changes can create costs to producers and consumers that are somewhat different in concepts than costs in the form of real resource expenditures. In order to measure these costs we need good data on the supply and demand functions for the markets on which prices change.

1- Costs of Physical Facilities:

Perhaps the easiest case to deal with is estimating the cost of a project that involves constructing and operating some type of physical facility like dams, irrigation works, and visitors center. Most of the relevant costs here

relate to the opportunity costs of the inputs used in the project, the capital costs of initial construction, and annual operating and maintenance costs that will extend over life of the project.

2- Costs of Public Regulation:

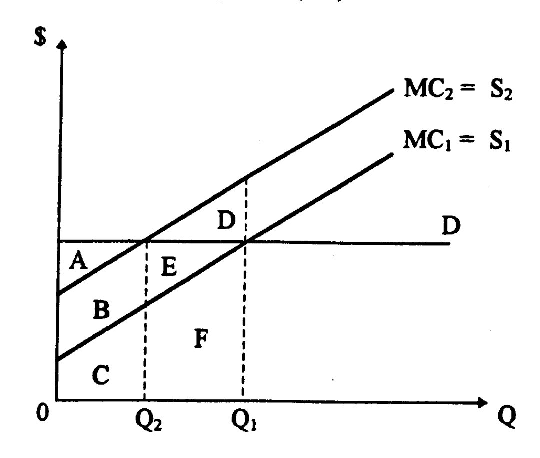
A great deal of public activity on natural resource issues is not related to physical projects but to public regulation of private actions. Cost estimation in this case is usually more difficult because it requires knowing something about the costs of the private operations that will be affected by the regulations.

The following figure shows the costs before and after regulations. The demand curve for timber harvesting by the collection of local companies is flat (D). Before the regulations their marginal cost curve equal to their supply curve was $MC_1 = S_1$. Thus total output was Q_1, total costs were (C + F). The effects of the regulation is to increase the costs of harvesting timber by an upward shift in the marginal cost curve to $MC_2 = S_2$.

If output were unchanged, the total increase in costs would be measured by the area (B + E + D). But the added costs in the face of a constant price will normally lead to output adjustment, output would fall to Q_2. Net benefits

before the regulations were (A + B + E) and net benefits after regulations were (A). There was a reduction in net benefits of (B + E).

Figure (3)

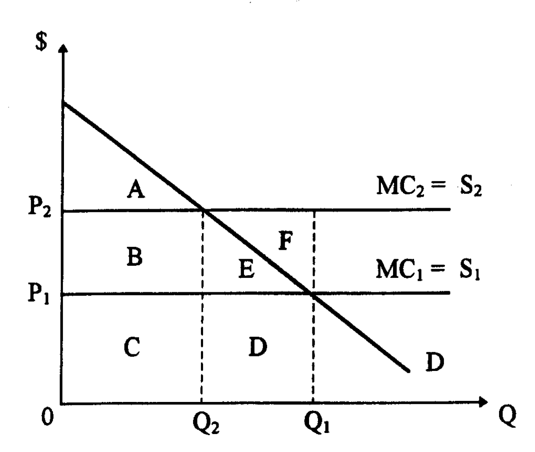


The information needed to measure the cost implications of the regulation includes: (1) The extent to which the marginal cost/supply functions will be shifted up by the regulation. (2) The extent of any output adjustments that firms will make as a result of the cost changes.

Figure (4) shows the effects of a regulation on consumers, where the regulation led to an output reduction from Q_1 to Q_2. The initial price-quantity situation is P_1 & Q_1. A regulation is now enacted that has the effect of lift-

ing the marginal cost curve to $MC_2 = S_2$. Price now rises to P_2 which makes consumers worse off. By how much?

Figure (4)



If we took the marginal quantity Q_1 and multiplied it by the price increase, we would get an amount equal to (B + E + F). But we would expect consumers to respond to the price increase. In the figure, the quantity drops to Q_2. Looking at the change in net benefits brought on by the cost increase, we see that this comes out to be (B + E). The adjustment in quantity reduces the cost to consumers relative to what would have been the case with no quantity change.

Chapter 6

Natural Resources and Market Failure

In this chapter we take up the question : Do markets involving natural resources normally function so as to give efficient or sustainable outcome regarding the rate of use of resources? There are good reasons for pursuing this question. Virtually all developed economies in the world are **market economies**; that is, the primary social institution relied upon to make decisions about resource use is the private market. And in recent years most of the economies that once operated on the basis of decisions and directives of central planning authorities have rejected that approach in favor of greater reliance on private markets. We are particularly interested, of course, in the operation of markets for natural resource goods and services.

Market Demand and Supply:

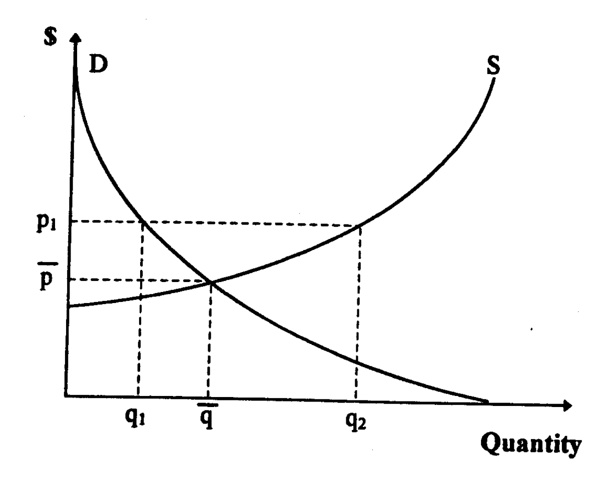
A market is a mechanism by which buyers and sellers negotiate transactions among themselves to transfer the ownership or use of a good or service at agreed upon prices. Markets vary from the most primitive, two people meeting face to face to trade a sack of potatoes in return

for two hours' worth of labor ; to the most sophisticated, a room full of people in electronic contact with their counterparts around the world buying and selling foreign exchange at prices that vary from minute to minute. But all markets essentially do the same job; they guide the flow of goods and services among buyers and sellers in terms of quantities and prices.

The basic market model, used to summarize these interactions, is shown in Figure (1). It shows two price-quantity relationships, one for demanders and one for suppliers. The **demand curve**, labeled D, shows the various quantities of the item that demanders will purchase at alternative prices. It is based on the notion of willingness to pay, and its downward slope illustrates the principle of **diminishing willingness to pay**. It is important to see the demand curve as comprising a menu of possibilities. It tells not only what the quantity demanded will be at the present price, but also what it would be if the price were higher or lower.

Figure (1)

Basic Model of Demand and Supply



The market demand curve summarizes the behavior of all the people who are in the particular market under consideration, those who have just bought something and those who might buy something if the price were lower. The demand curve reflects their incomes, tastes and preferences, and other relevant economic factors of their circumstances. If any of these underlying factors change, the market demand curve will change.

The supply curve, labeled S, represents the behavior of sellers of this good or service. Its upward slope is a re-

flection of increasing marginal production costs, and its exact shape how steep it is, how far to the right or left is related to input prices used in production and the fundamental technologies employed in the production process. Like the market demand curve, a market supply curve basically consists of a large number of potential output levels, only one of which will be realized during any particular time period.

Market Quantities and Prices:

Given the demand and supply curves as shown, there is only one price where the quantity demanded by consumers is the same as that supplied by producers : This is when the price is $\overline{p}$, the quantity is $\overline{q}$. At any other price, there is a discrepancy between quantity supplied and quantity demanded. At a price of p_1, for example, suppliers would attempt to supply q_2 units of this item, while demanders would desire only q_1 units. As long as the demand and supply curves remain the same, something has to give. Excess supply normally will lead to downward pressure on prices; as prices go down, the quantity demanded will increase. So market adjustments in this case will move prices and quantities toward the **equilibrium** pair, $\overline{p}$, $\overline{q}$. Prices that are temporarily below $\overline{p}$ will lead to excess demand,

that is, quantity demanded by consumers in excess of quantity supplied. This puts upward pressure on price and increases in quantity supplied toward the equilibrium levels.

In a dynamic economy we usually don't see prices and quantities that stay constant over a long period of time. That's because the underlying factors that affect the demand and supply functions are regularly changing. Demographic growth shifts demand curves, and technical change shifts supply curves, for example. Shifting expectations affect how demanders and suppliers will react on current markets. So over time we often see prices moving upward or downward and not necessarily coming to some resting place as in equilibrium. But the model is still very useful, because it explains how the basic market process operates.

The essence of this process is that it is the interaction of buyers and sellers, actual and potential, that causes prices and quantities to adjust, normally toward some equilibrium level. For price-quantity combination p*, q* to materialize, it is not necessary for some economists first to figure out what they are, or for a politician or public administrator to intervene and enforce them by fait. It happens as a result of the more or less unrestricted interactions and transactions among buyers and sellers.

Market Efficient and Externalities:

Markets tend toward equilibrium values like $\bar{p}$ and $\bar{q}$ in Figure (1). But how do we know that these values represent those that are **socially efficient** ? Refer back to Figure (1) in the previous chapter. Social efficiency, identified as q* in that model, is defined as the rate of output at which marginal social benefits (MSB) are equal to marginal social costs (MSC). Thus, at least two things have to be true for market outcomes to be socially efficient: The market demand curve and the MSB curve have to be the same, and the market supply curve and the MSC curve have to be the same. If these two conditions are met, markets will tend to generate socially efficient outcomes; if they are not met, markets will not be efficient.

Market demand curves register the willingness to pay of the participants in those markets. Thus, to say that the market demand curve must be the same as the MSB curve is to say simply that there are no sources of social value that are not registered by market participants themselves; in effect, nothing is left out. Similarly, market supply curves are based on the costs that impinge on the private parties who make up the supplying entities on the market business firm, for example. Thus, to say that the

supply function and the MSC function are the same is to say simply that there are no sources of cost to members of society that are not registered in those private cost / supply curves.

Our job, then is to consider the conditions under which these relationships will be consistent, MSB and D, and MSC and S. But before this, one other condition has to be true for markets to be socially efficient: They must **be competitive**. Competition means that there are no possibilities for buyers and sellers to exert influence on the market; suppliers cannot band together and collude to produce a higher price; nor may buyers do anything on the other side of the market to force lower prices. Competition requires several things: a large number of buyers and sellers, so as to foreclose any one of them gaining a controlling position, and a set of rules defining the limits of acceptable behavior. Of course in real-world markets it hardly ever is a question of the simple presence or absence of competition, it is always a question of how much. "Acceptable" levels of competition are those which allow a market to achieve efficiency; competition that is either too weak or too strong will make it impossible for markets to do this.

Let us now return to the question of whether market demand curves and market supply curves are equal to, re-

spectively, marginal social benefits and marginal social costs. We will first take up the cost question.

External Costs:

To pursue this point we reiterate the distinction between social costs and private costs. Social efficiency is defined according to social costs, while supply curves are based on private costs. Under what circumstances might there be a discrepancy between the two? Consider the costs of harvesting the trees in a forest to get timber that will ultimately be turned into building supplies. Private costs in this case are the costs incurred by the logging companies to get the trees out of the forest: like labor, equipment, and fuel costs. These are the costs (which we have called marginal private costs, or MPC) that show up on the profit-and-loss statement of the logging companies at the end of the year. These private costs are legitimate social costs, because these inputs could have been used elsewhere in the economy to produce something else.

But in this case, the full social costs of logging may include other cost elements as well. The government may devote some resources to the operation, for example, in constructing logging roads into the forest. Social costs may also include ecological costs. Certain forests may have

unique ecological values that are diminished as a result of the logging. These costs may be very difficult to measure in practice, but they are legitimate social costs nonetheless.

The difference between private costs and social costs is called **external costs**. External costs, in other words, are costs incurred by people who are not party to the decisions that give rise to them. In the forestry example the external costs result from the decisions of the logging companies, but they are incurred in part by others, in particular those people who place value on the ecological characteristics for the forest.

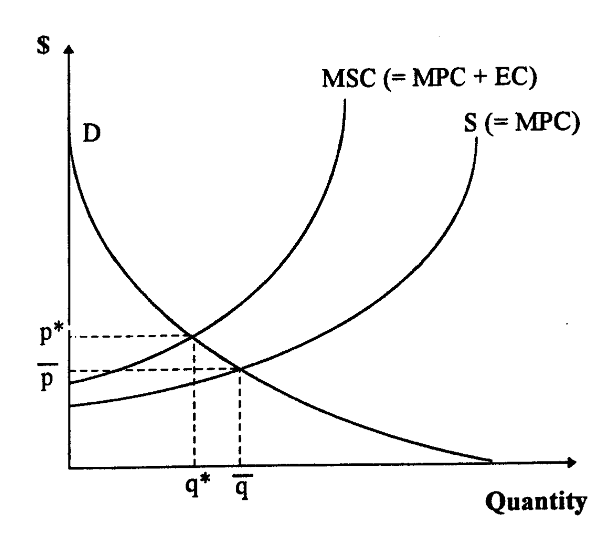
As another example, consider a collection of paper mills located on a river. They produce paper and in the process emit residuals into the river. The water quality of the river is reduced, which leads to damages suffered downstream by recreators and communities using the river as a water supply source. This situation is illustrated in Figure (2). The market supply curve (labeled S) depicts the behavior of the supplying firms: the paper mills. The factors determining the shape and height of this supply curve are the costs that impinge directly on the profit-and-loss sheets of these mills such items as labor costs, energy costs, raw materials, and buildings. These costs and the technology of paper production determine the quantity of

inputs needed to produce various quantities of output, their marginal costs of paper production, and therefore the market supply curve of paper. But the downstream external costs are legitimate social costs that need to be included when determining the socially efficient rate of output of paper. The curve labeled MSC is the market supply curve plus the external costs (EC). MSC thus includes all the social costs of producing paper. Assume further that the demand curve D registers accurately the full social benefits of this product, Then the **socially efficient** quantity and price of paper are q* and p*, while the market will tend to settle at q and p . In other words, when environmental external costs are involved, normal market operations will tend to **quantities that are too high and prices that are too low,** relative to socially efficient levels. From a policy perspective the question is how to get these external costs **internalized,** so that the paper mills will choose output level q* rather than q .

Figure (2)



Basic Model of Demand and Supply



External Benefits:

On the other side of the market, to say that the demand curve must be the same as the social marginal willingness-to-pay curve (social demand curve) is to say that the market demand curve must include all the social benefits arising from the consumption of the good or service in question. Nobody is left out; all benefits are included, no matter to whom they accrue. If, on the other hand, significant social benefits accrue to people who are not direct

participants in the market in question, then the market results are unlikely to be efficient. They may also be regarded as inequitable.

External benefits can be present in the same direct way that external costs are present. Suppose I consider buying a new lawn mower. I evaluate the different models available and the important characteristics of each, especially their prices. Another important feature is their noise level; in general, I can get a quieter machine if I am willing to pay a somewhat higher price. In making my decision I try to balance these two factors in terms of my own tastes and preferences and budget. But buying a quieter model would also confer benefits on my neighbors, in the form of a generally quieter neighborhood. For my purchase to be fully socially efficient, not just efficient from my own perspective, these other benefits need to be included. These are **external benefits** ; they accrue to somebody other than the person making the decision that produces them.

Suppose I own a farm that contains, besides a certain area of cleared fields, an area of woods. I maintain the woods because I like to produce maple sugar from the maple trees that are on it. In making a decision about how much wooded acreage to maintain, I weigh the benefits in terms of revenues from maple sugar, with the costs in

terms of not having the land available for pasture or cultivation. But suppose some interesting wild animals live in these woods. They are interesting perhaps because they are endangered or because people like to see them occasionally or simply know that they are there. The benefits produced by the wild animals are largely external benefits; they accrue to people who are not involved in the decision about how much of my land to keep in woods. When external benefits are involved, market outcomes will tend to be inefficient, the outputs responsible for the external benefits will be too small, and its price will be too low.

External benefits are present whenever **public goods** are involved. A public good is a good that, once made available to one person, automatically becomes available to others.

When public goods are involved, private markets will find it difficult to supply socially efficient levels. Table (1) contains some numbers. They refer to the willingnesses to pay of three individuals for a program to restore bald eagles in a particular habitat. It also has a column showing the marginal cost of this program, which can be carried out at three different levels: light, moderate, or extensive. Comparing the aggregate marginal willingness to pay with the marginal cost shows that a moderate restoration pro-

gram would be the one that maximizes net benefits to this society of just three people.

Table (1)

Benefits and Costs of Restoring Bald Eagles

	Marginal willingness to pay				
	A	B	C	Aggregate	Marginal cost
Light	50	10	25	85	40
Moderate	30	5	10	45	40
Extensive	10	0	5	15	40

Suppose, then, a private firm were to engage in this restoration program. It puts up the $ 80 required for a moderate-level program, and then asks the three beneficiaries for contributions, commensurate with their willingnesses to pay, to cover the costs. Because of the nature of the good involved, it now becomes possible for the individuals to **free-ride**. Free riding means holding back on one's contribution so as to get the benefits while bearing less of the cost. This is possible because it is a public

good; once available, it produces benefits for everybody, regardless of how much or little they have contributed.

Open-Access Resource:

We come now to an important class of natural resources the utilization of which typically gives rise to external costs, and the effective management of which typically involves public goods and external benefits. For these reasons they are often overutilized. The resources in question are called **open-access resources**. An open-access resources is simply one that is open to unrestricted use by anyone who might wish to utilize it. The classic example has always been the ocean fishery. Until fairly recently most fisheries, for example the North Atlantic groundfish fishery, could be fished by anybody who had a boat and the appropriate gear. Another example is terrestrial wildlife in North America; historically hunters have had unrestricted access to stocks of wild game, such as birds, deer, buffalo, or elk. Open-access resources need not be extractive resources. Public parks, where visitors may enter with out restriction, are also open-access resources.

Open-access typically leads to overuse. We can illustrate this with a very simple example, that of a small public beach. Being public, the beach is open to use by

anybody who wishes to visit. This is somewhat artificial, of course, because today beach access is often restricted in some way, for example to citizens of a particular community. The use restrictions are usually a response to the problems stemming from open access. We can learn what these are by considering a simple numerical example of an open-access resource.

The essential data are shown in Table (2). This small beach lies a number of miles from a town center from which all the visitors originate. The first column shows the potential number of visitors that might make use of the beach on an average day; it runs from one to ten (it's a small beach). The next two columns show willingness to pay, first marginal and then total. Marginal willingness to pay is the MWTP, given that the number of visitors is currently at the level indicated. For example, if today there are two visitors, the marginal willingness to pay of the third is $ 20. Note and this is critical that MWTP stays constant at $ 20 until there are four visitors; after that it begins to fall off. The reason for this is congestion. At higher levels of visitation, the quality of the beach diminishes because of congestion, so the MWTP by additional visitors declines.

Table (2)

An Open-Access Resource: Public Beach

Number of visitors	Individual marginal willingness to pay	Total willingness to pay (WTP)	Cost per visit	Total costs (TC)	Total WTP minus TC
1	$ 20	$ 20	$ 12	$ 12	$ 8
2	20	40	12	24	16
3	20	60	12	36	24
4	20	80	12	48	32
5	18	90	12	60	30
6	16	96	12	72	24
7	14	98	12	84	14
8	12	96	12	96	0
9	10	90	12	108	-18
10	8	80	12	120	-40

On the cost side, we assume that the cost of visiting the beach is the same for every visitor, $ 12. We are assuming that the travel costs for each of the visitors to get to the beach are basically the same. We assume that there are no entry fees charged at the beach. The fifth column shows total visitation costs.

The efficient level of beach visitation is evidently four people per day. This is the level that maximizes the net benefits of the beach. We will now see, however, that

if beach access is uncontrolled, visitation will be higher than this efficient level. Suppose that there are currently four people using the beach and that a fifth is trying to decide whether to visit. The costs to the fifth visitor are $ 12, her willingness to pay is $ 18; her visit will apparently lead to net benefits of $ 6, so she visits. But a sixth person will also realize positive net benefits from a visit, as will a seventh. It is only when we get to the eighth potential visitor that net individual benefits fall to zero, and for the ninth and tenth visitors, they are negative. So we can reason that with open access, total visitation will go to 7 visitors and possibly to eight (if the MWTP for the eighth were just slightly higher). This is substantially higher than the socially efficient visitation level.

In this case open access leads to a substantial overshoot-excessive use rates relative to efficient levels. The main reason for this is what are called **open-access externalities**. These are externalities that the users of the resource inflict on one another in the form of diminished resource value. In the beach case the diminished value stems from increased congestion. When the fifth prospective visitor is deciding whether to visit, she compares the gain she will have of $ 18 with the cost of $ 12 and acts accordingly But in proceeding with her visit, she reduces the

value of the beach to the four already there, from \$20 to \$18 for each one, a \$2 loss times 4 visitors equals a total external cost of \$8. This external cost is in fact equal to the individual gain of the fifth visitor and, for the sixth and seventh visitors, the individual gain would be less than the externality losses .

The exact nature of the open-access externalities will differ from one type of resource to another. For the beach it was externalities in the form of beach congestion, which reduces the value of a beach visit. For hunters sharing a territory, including fishers working the same fishery, it is the added cost of harvesting, which stems from two sources: hunters more often intrude on one another, and higher catch rates mean lower stocks.

Markets and Intertemporal Efficiency:

Compare panels (a) and (b) in Figure (3). They represent two different versions of the output from, let us say, a group of timber companies. The output in this case is cubic feet of timber harvested during a particular year from a given geographical region. Panel (a) shows the classic market demand and supply curves. Panel (b) shows the socially efficient level of output, given by the balance of marginal social benefits and a function representing the

total of marginal current costs and user costs. Will q_0^m and q_o* be the same? Evidently they will be if all functions in the two panels are the same. Note that now the output has a time index; it is the output of the first period, recognizing that in the dynamic case this is just the first year of a multiple-period production program.

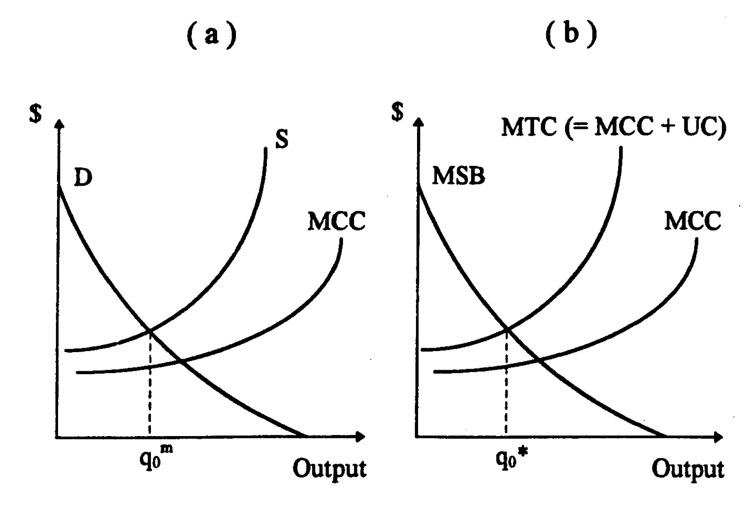
If there are no external benefits, then MSB = D. But on the cost side things are trickier. Panel (a) shows MCC (marginal current costs) and the supply function S. Here we have to recognize that there can be a difference in user costs seen from the private and social points of view. Private user costs incorporate future revenue changes impinging on firms as a result of decisions made today. The market rate of output, labeled q_0^m, is based on private user costs. will this output level be intertemporally efficient from the social viewpoint ?

Panel (b) shows the MTC as the summing together of marginal current costs (MCC) and user costs (UC). In this case user costs are defined as future costs from the **social standpoint**. Evidently the market rate of output (q_0^m in panel a) will be equal to the socially efficient rate of output (q_0* in panel b) if and only if the private user costs actually taken into account by suppliers are equal to the user costs considered from the standpoint of society as a whole.

Figure (3)



Markets and Intertemporal Efficiency



Assume for the moment that there are no classic external costs of the type we discussed in the previous section (like emissions from pulp mills or ecological destruction by timber firms). Then the only way we can get a difference between S and MTC is for private future costs to be different from social future costs. For the most part, we are concerned with factors that may **make private future costs** lower than true **social future costs**, because when this is the case, the market rates of output will be too high relative to the output that is intertemporally efficient.

Markets and Discounting:

There are several reasons why today's markets may function in ways that are not intertemporally efficient. Remember that the future costs of today's actions are in terms of **present value**; in other words, it is a future consequence **discounted** back to the present period. On the market this discounting will occur at discount rates that today's market participants apply, according to their own views about the affects of time and its impacts on relative values to themselves. But suppose, in some wider social sense, people typically apply discount rates that are too high. There have been many observers through the years who have thought that the average person is too short-sighted, that they do not put sufficient weight on the future effects of their actions. In other words, they use private discount rates that are too high.

If this is true, then future costs affecting decisions of market suppliers will be too low, relative to what might be called the socially efficient levels of future costs. And if this is indeed true, then contemporary natural resource market will produce at levels that are too high and at prices that are too low, relative to the levels that are socially efficient. Of course, like a lot of other things, it is easy to say this on a conceptual level. It is harder to figure out if it actually happens in the real world.

Chapter 7

Efficient and Sustainable Use of Natural Resources

We look at economic efficiency from two angles: state efficiency and dynamic, or intertemporal, efficiency. A state of affairs that is efficient in the static sense is one that is efficient strictly from the perspective as a single time period, in particular the present one. In the spring a farmer plants a crop, later harvesting it and shipping it to market. A timber harvesting firm cuts down a number of trees this year and also ships them to market. A public agency allows a certain number of visitors into a park this year. These decisions will be efficient in the static sense if they are undertaken in light of the consequences flowing from them this year only.

Dynamic, or intertemporal, efficiency means a situation that is efficient when account is taken not only of the present year but all future years as well. A decision is intertemporally efficient if it takes into account all the consequences flowing from it, those occurring this year and those in the future. If there are no future consequences stemming from today's decision, a static perspective is

sufficient also to achieve dynamic efficiency. Consider the farmer. There is essentially no connection between this year's decision as to how many acres to devote to cantaloupes and anything that will happen in future years. This decision can be made, and harvests produced, with essentially no future consequences . In this example a decision made only on static grounds will capture all the consequences that are involved.

But this is not true for the company doing the logging. Cutting down and replanting trees this year means there will be no trees to cut on this parcel until such time as the new trees mature. There are clearly future consequences flowing from today's decisions. Pumping petroleum out of an underground deposit is also a decision of this type ; pumping more today means having less to pump out in the future. In cases like this decisions made only on static grounds (considering only current consequences) will be very different from those made on dynamic grounds (considering both current and future consequences).

The next two sections deal, respectively, with static and dynamic economic efficiency. After that we turn to the idea of sustainability, an idea that has become widely popular in recent years as a possible alternative, or addi-

tional, criterion for evaluating the long-run consequences of natural resources decisions.

Static Efficiency:

To understand the notion of **static efficiency** we bring together the two major concepts, marginal willingness to pay and marginal cost. This is done in Figure (1). The horizontal axis depicts alternative quantities of the output of a good or service and the vertical axis has a value scale. The MSC curve represents **marginal social cost**, that is, the marginal costs to all of society of producing this good or service. The MSB curve represents **marginal social benefits**, which are measured by the marginal willingness to pay of all members of society for this good or service. Both MSB and MSC curves are aggregate relationships. They represent the summed marginal willingness to pay and summed marginal cost relationships of all the people and firms in our "society". Since nothing and nobody is left out, they are called "social". The rate of output that is socially efficient is the one that yields the maximum **net benefits to society**. Net benefits refer to the total benefits of the thing that is produced minus the value of the resources used up to produce it. The total benefits of a quantity of output are given, as we saw earlier, by the area

under the social marginal willingness-to-pay curve. At a quantity of q^* in Figure (1), the total social benefits of output are equal to the area labeled a + b.

Total costs are equal to the area under the social marginal cost curve. For the quantity q^* in Figure (1), this is shown as area b. Thus the **net social benefits** of the output level q^* is (a + b) - b = a. Net benefits are equal, in other words, to the difference between the area under the social marginal willingness-to-pay curve and social marginal cost curve.

It is straightforward to show that q^* is the rate of output that maximizes the net social benefits associated with the production of this good or service. To do this, take some other output level, such as q_1 in Figure (1). The net benefits of this output are derived as follows:

Total benefits : a + b + d

Total costs : b + c + d

Benefits - cost: a - c

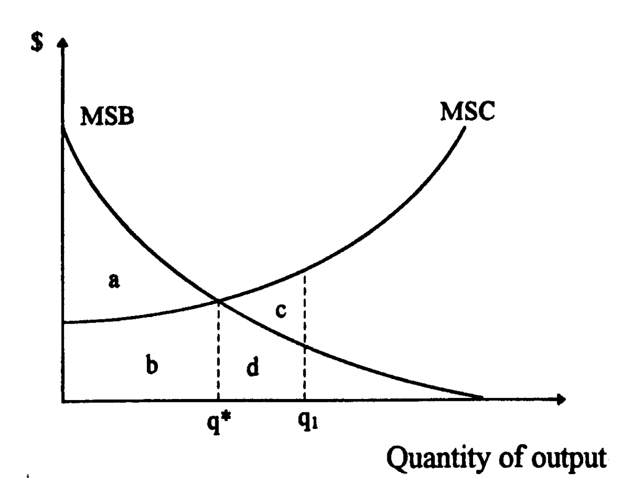
In other words, net social benefits are equal to what they would have been had output been q^*, minus the quantity c. We can conclude that net social benefits are definitely lower at q_1 than at q^*. In fact this same conclusion can be drawn about any output that is different from q^*.

Of course the condition that identifies output level q* uniquely is that MSB = MSC at that output. The notion of efficiency involves a trade-off between willingness to pay and production costs. To the left of q*, an additional unit of output would add more to social benefits than to production costs (i.e., marginal willingness to pay exceeds marginal cost) while to the right of q* the opposite is true. At q*, therefore, these two quantities are in balance, marking the socially efficient rate of output.

The reason this is called static efficiency is that it is based on a balance between two contemporaneous, or current period, quantities. Quantity of output, marginal benefits, and marginal cost are all values pertaining to the current year; there is nothing in this simple model that applies to some other time period, for example, future period marginal costs as they might be affected by this period's output rate.

Figure (1)

Static Social Efficiency



Dynamic (Intertemporal) Efficiency:

By **dynamic** or **intertemporal efficiency**, we also refer to a state of affairs in which there is a maximum of net benefits; but now benefit and cost categories are extended to include not only those of the present period, but also the future consequences flowing from today's decision.

Let us look explicitly at the criterion to be maximized in the search for intertemporal efficiency. It can be written as follows:

$$\text{Present value of net benefits} = \text{Net benefits in year 0} + \text{Net benefits in year 1}\ \frac{1}{1+r} + \text{Net benefits in year 2}\ \frac{1}{(1+r)^2} + \ldots\ldots$$

or

$$\text{Present value of net benefits} = \text{Net benefits in year 0} + \text{Sum of all discounted future net benefits}$$

The present value of net benefits can be thought of as consisting of a sum ; the first term in the sum is the net benefits in the current period, while the second term shows the net benefits of all future periods **discounted** by the appropriate factors. Dynamic efficiency requires that current and future rates of use be chosen that make this sum as large as possible. What makes things complicated is that there is normally a **trade-off** ; decisions that increase the net benefits of using a natural resource in the present period often have the effect of decreasing net benefits from the resource in the future. It is this problem of finding the appropriate balance between present and future that characterizes the concept of dynamic efficiency.

Clearly, the discount rate plays a critical role in intertemporal efficiency. Our idea of intertemporal efficiency depends, in other words, on the notion that future net

benefits of natural resource use are to be discounted in order to determine their present values. Discounting future net benefits to help identify social efficiency is controversial..

We can take the last expression and convert it into marginal terms. Remember that "marginal" refers to the extent to which something changes. Thus if there is a one-unit change in today's rate of resource use, we have

Change in the present value of net benefits	=	Change in benefits of present period	-	Change in costs of present period	+	Change in discounted value of future net benefits
(MNB)		(MB)		(MCC)		(UC)

Which can be rewritten, using the indicated designators :

$$MNB = MB - MCC + UC$$

The designator MCC can be thought of as "marginal current costs" ; that is, marginal costs incurred in the current period. UC stands for **user costs**. User costs, in other words, is the name that will be given to the change in the discounted value of future net benefits. Anything that affects these future net benefits, in other words, is expressed through what we are calling user costs.

If the choice of today's output actually have no future consequences, then these user costs would be zero ; in effect, we would be back to a static situation. The decision about how many acres of cantaloupes to grow this year on a 100-acre farm is strictly a static decision. There are no future consequences flowing from this decision, only contemporary ones ; hence, user costs in this case are zero. Or suppose the decision is how much water to take out of a passing river to irrigate some crops. Increasing or decreasing the amount withdrawn is not likely to have an impact on future water availabilities in the river, hence the user costs of the water are zero.

But in case where user costs are not zero, intertemporal efficiency requires that today's rate of output be set so that today's marginal willingness to pay is equal to the sum of today's marginal costs and user costs. This is depicted in Figure (3) . This shows the current year market for a natural resource good or service, for example, the number of units (tons, barrels) of a resource harvested or extracted, or the number of acres of land devoted to a park or wildlife refuge. MCB (for marginal current benefits) shows society's valuation of this resource-based good or service in the present period, while MCC shows the social costs of harvesting or extracting or otherwise making it

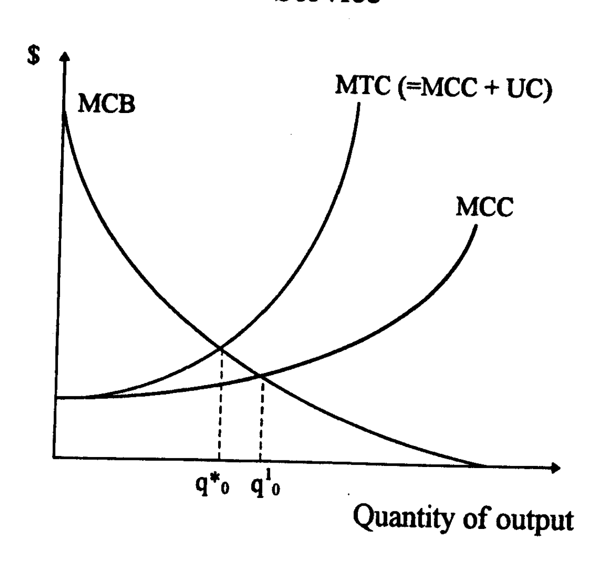
available this year. To repeat, if this were a static problem, these would be the only relevant relationships and the efficient rate of output would be q_0. But assuming there is a user cost of some amount, this has to be added to today's harvest cost, giving the overall marginal cost function labeled MTC (= MCC + UC). The intersection of this curve with MCB gives q_0^* as the intertemporally efficient rate of output in the current period.

User cost is, in effect, the factor that accounts for the future resource-related consequences of today's decisions. Think of user cost as being a single term that is used to show the discounted present value of the sum of all future consequences stemming from today's decisions. Clearly, the higher the user cost, the more will the MTC curve diverge from the MCC curve, in other words, the bigger the difference between dynamic and static efficiency. The exact form that user cost will take depends on the problem at hand. If the problem is a simple one, say, with just two time periods and a strictly nonrenewable resource, user cost will be simple also ; it will be equal to the discounted value of extracting one less unit next year. But if this situation is complex, user cost will also be complicated. Suppose the issue is how current output decisions affect future species diversity over the next century. This is

a biological complex, difficult-to-measure, long-run problem. User cost in this case will be very hard to estimate. Conceptually, however, it is clear. It is the present value of all the future consequences arising from today's natural resource use decisions.

Figure (3)

Intertemporally (Dynamically) Efficient Rates of Output of a Natural Resource Good or Service



Why Discounting?

Intertemporal efficiency, which maximizes the welfare of the present generation, involves discounting the future values of benefits and costs. This is a controversial issue. Discounting appears to put a lesser value on future net benefits than on net benefits occurring closer in time. Furthermore, discounting is done from the perspective of the current generation. Is this fair to future generations? By discounting are we not giving short shrift to the interests of future generations, who apparently are not around to represent themselves? There are many who feel that discounting is essentially anticonservationist ; by putting a higher value on today's output relative to future output, we tilt the production profile toward the present. How valid is this objection? There are several different parts to this question, which we will take up in turn.

One question to ask is whether people actually discount in practice, in their everyday lives. And the answer here is yes. The fact that there are positive rates of interest in the world is partly a reflection of the fact that people place a higher value on something today than on that same something happening off sometime in the future. Direct research has also been done on the discount rates applied by people. In one recent study a large number of people were

queried on the question of trade-offs between public programs that would save a certain number of lives today as compared to other programs that would save some larger number of lives at varying distances in the future. By asking enough people to choose among enough different combinations, it was possible to find out the relative values among which they were indifferent, and therefore their implied discount rate. For example, if a person responded that she was indifferent between a program that would save 10 lives today and one that would save 500 lives 50 years from now, the implied rate of discount that the person is applying to these payoffs is about 8 percent.

The results of this research are shown in the following tabulation :

Length of time period (years)	Implied discount (%)
10	12.0
20	9.0
30	7.0
40	6.0
50	5.0
60	4.8
80	4.2
100	3.8

These results show that the farther in the future is the event being considered, the lower is the discount that people apply to it. For events that are only 10 years distant, the average rate of discount was about 12 percent ; for events that will happen in 50 years, the discount was 5 percent; and for 100 years, the discount was 3.8 percent.

Since people (in both their consumer and producer roles) do discount, on average, in their everyday lives, may we not take this as implying that we ought to discount when assessing the social desirability of natural resource use rates ? Some observers have taken the position that when individuals use some positive rate of discount to evaluate future benefits and costs, they are demonstrating a defective capacity for weighing the future consequences of their actions ; they are being myopic. To believe this, one has to believe that people who discount are somehow less in touch with the benefits and costs that impinge upon them than are certain observers. This is not only condescending, it is also scientifically dubious-especially so when we are looking at the behavior of people at markedly different wealth levels. People with low wealth positions clearly have an incentive to put heavy weight on near-term payoffs over future ones. It is not easy to see how the lives of these people would be improved by asking them in effect to put

more weight on distant (in time) values and less on the immediate requirements of making and supporting their families.

From the perspective of the **current generation**, therefore, the arguments for discounting future benefits and costs are reasonably compelling. The rub comes when we wish to factor in the welfare **of future generations**. Does discounting put future generations at a disadvantage relative to those people alive today? Or to put it the opposite way, does discounting tend to improve the welfare of today's generation at the expense of future generations? Would we be better off today if our grandparents had used lower discount rates in their decisions? If future generations could somehow have a seat at today's table, would they agree with the discounting practices of today's decision makers? If we could show that future generations will be better off if people alive today discount the future, we could agree that discounting was both efficient and fair to the future. But can we show this?

The first point to be made is that higher discount rates are not invariably anticonservationist, in fact, plausible circumstances exist in which low discount rates work against conservation rather than the reverse.

The Issue of Sustainability:

Sustainability has come to be a rallying cry and an organizing principle for much of the subsequent public discussion about natural resource and environmental policy. In that arena it has clearly served to encourage a longer-run perspective in policy discussions and decisions. But is it a useful criterion for evaluating resource use decisions ? In order to answer this, it has to be defined more explicitly. According to the Commission report, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Without getting into arcane discussions of the meaning of words like "compromise" and "needs", one way of interpreting this operationally might be the following Any actions on the part of people today that would make future generations worse off than we are today is to be called nonsustainable. Sustainability implies, therefore, that future generations are to be no worse off than today's generation.

But worse off in what respect ? Suppose we insist that it be in the sense of the physical supplies and availabilities of natural resources. The condition for sustainability would be that future generations should have no smaller

supplies than currently exist. There is no particular conflict between this and intertemporal efficiency when the subject is **renewable resources**. Intertemporal efficiency normally implies constancy of the resource stock through time, which would be in agreement with this particular notion of sustainability. For **nonrenewable resources**, however, there is obviously a problem if sustainability is to be defined in terms of physical availability. In this case any positive rate of extraction today obviously must lead to reduced availabilities at some time in the future.

Sustainability defined in terms of physical quantities might still be a viable idea if it were interpreted as nondiminution of the total of natural resources rather than any particular single resource. In this case the drawing down of a nonrenewable natural resource could perhaps be compensated for by augmenting supplies of a renewable resource. We might, for example, increase the acreage of preserved ecosystem in one region as quantities of coal or some other mineral are extracted elsewhere.

But the practical usefulness of a procedure like this is open to question. A basic problem is knowing the "exchange" ratios between resources, for example how many acres of preserved wetlands are worth 1 ton of extracted coal or other mineral. To make this approach fea-

sible, we switch from a physical-units notion of sustainability to one that is based on value. This would make it possible to assess different resources in terms of a common metric that allows comparison and aggregation. If natural resources are converted to values, then an injunction to preserve them in terms of their aggregate value is at least operationally feasible, whether or not the rule makes sense in terms of preserving or enhancing human welfare.

Questions On Part I

Question # 1:

1- Give an example of a policy that is efficient but not equitable and of one that is the opposite. Do you think that, in general, efficient policies are likely to be equitable, and vice versa?

2- From a political perspective, why do subsidies and property rights policies often get more support than taxes and command-and-control policies?

3- Distinguish between use values and non use values in the specific case of preserving the quality of water in an underground aquifer. How might you measure the different types of benefits in this case?

4- What types of questions might you put in a contingent study being done to estimate the benefits of limiting timber harvesting in certain areas?

5- What is the conceptual relationship between use values consumptive values, and market values?

6- Distinguish between use values and non-use values in natural resource economics?

Question # 2: Multiple Choice:

1- In terms of an optimal environmental quality, the producer will maximize his total profit when:

(a) Marginal private benefit (MPB) equals zero.
(b) Marginal revenue equals marginal cost.
(c) Marginal private benefits curve intersects with horizontal axis.
(d) All of the above.

2- As the level of production increases:

(a) It is assumed that the marginal private benefit increases.
(b) It is assumed that the marginal external cost increases.
(c) Marginal revenue exceeds marginal cost.
(d) All of the above.

3- The optimal level of environmental quality occurs when:

(a) All environmental impacts should be stopped.
(b) The level of pollution equals zero.
(c) The marginal private benefit equals the marginal external cost.
(d) All of the above.

4- The optimal level of environmental quality occurs when:

(a) The level of waste equals the assimilative capacity.
(b) Marginal revenue equals marginal cost.
(c) Marginal private benefit equals marginal private cost.
(d) All of the above.

5- When the level of waste exceeds the assimilative capacity:

(a) The optimal level of environment decreases.
(b) Assimilative capacity curve shifts upward.
(c) The assimilative capacity increases.
(d) The marginal external cost shifts rightward.

6- The ecologically stable output means:

(a) The level of output which marginal private benefit equals marginal external cost.
(b) A zero level of pollution.
(c) External cost exceeds private benefit.
(d) None of the above.

7- Marginal cost of one person to his neighbor is:

(a) Negatively related to units of pollution.
(b) Positively related to units of pollution.
(c) Equals zero when pollution equals zero.
(d) a and c are right.

(e) b and c are right.

8- Which of the following statements is not correct:

(a) All economic activity involves the production of waste residuals.

(b) The perfect recycling of wastes is impossible.

(c) It is possible to convert residuals completely into useful forms.

(d) All of the above.

9- If the property rights were given to the producer of pollution:

(a) The producer would have no legal liability for any pollution he produced.

(b) The producer would have legal liability for any pollution he produced.

(c) The affected person would have legal liability to prevent pollution.

(d) None of the above.

10- Effective public policy depends on:

(a) good information on hoe environmental system works.

(b) good government agencies.

(c) good understanding of pollution mechanism.

(d) all of the above.

11- Pollution control policies imply:

(a) trade-off between costs and benefits.
(b) trade-off between public sector and private sector.
(c) trade-off between private goods and public goods.
(d) all of the above.

12- By pollution damages we mean:

(a) negative impacts of natural resource use.
(b) negative effect of natural crises.
(c) negative effects of bad institutions.
(d) nothing of the above.

13- Emission damage functions show:

(a) the relation between different levels of emission and losses in money terms.
(b) the relation between changes in level of emission and changes in losses in terms of money.
(c) accumulated damage and losses in terms of environmental quality.
(d) accumulated losses and accumulated pollution in physical terms.

14- Ambient damage functions show:

(a) the relationship between concentration levels of particular pollutant and the resulting damage.

(b) the same relationship as the emission damage function.
(c) the money losses resulting from each kg. pollution.
(d) nothing of the above.

15- Shape and height of a damage function depends on:

(a) available technology of production.
(b) density of population.
(c) abatement cost.
(d) (a, b) correct.

16- If the marginal damage function is rising then:

(a) total damage function increases at a decreasing rate.
(b) total damage function increases at an increasing rate.
(c) total damage function decreases at an increasing rate.
(d) total damage function decreases at a decreasing rate.

17- Pollution threshold means:

(a) the level under which pollution is safe.
(b) the level above which pollution is not safe.
(c) the level at which pollution should stop.
(d) the level at which efficient abatement take place.

18- Total damage can be shown graphically as the:

(a) area under marginal damage function.
(b) area above marginal damage function.
(c) area around marginal damage function.
(d) area to the left of the marginal damage function.

19- Marginal abatement cost function shows:

(a) negative relation between level of emission and added cost of abatement.
(b) positive relation between level of abatement and added cost of abatement.
(c) negative relation between level of abatement and level of emission.
(d) nothing of the above.

20- Equimarginal principle means:

(a) allow every firm an equal ratio of pollution.
(b) allow every firm an equal level of abatement.
(c) enforce abatement measure so that marginal abatement cost is equal for every firm.
(d) equiproportionate ratio of pollution.

21- If equimarginal principle hold then:

(a) all pollutant will have the same marginal abatement cost.
(b) all pollutant will have the same marginal pollution cost.

(c)all the pollutant will have the same level of emission.

(d) nothing of the above.

22- Efficient level of pollution is obtained at:

(a) zero level of pollution.

(b) positive level of pollution.

(c) total pollution is maximum.

(d) cost of abatement = cost of pollution.

(e) marginal cost of abatement = marginal cost of pollution.

23- Enforcement cost if added to abatement cost:

(a) raises the level of emission.

(b) reduces the level of pollution.

(c) reduces the level of damage.

(d) raises the level of abatement.

24- Natural resource economics is:

(a) concerned with the study of natural capital economics.

(b) concerned with the study of ecological balance.

(c) concerned with the geography of resource allocution.

(d) concerned with the study of laws of thermodynamics.

25- Environmental economics is concerned with:

(a) the study of optimal quantity of pollution.
(b) the study of optimal quantity of environment.
(c) the study of environment resource management.
(d) all of the above.

26- Which of the following uses are non extractive use of the forest:

(a) recreation.
(b) ecosystem protection.
(c) flood control.
(d) all of the above.

27- Which of the following is a direct use value of the forest:

(a) timber.
(b) flood control.
(c) carbon storage.
(d) water catchments.

28- The resource will not be depleted if:

(a) rate of extraction is trivial.
(b) rate of extraction is greater than zero.
(c) rate of extraction is non significant.
(d) rate of extraction is less than rate of replenishment.

29- If the rate of recyclability is 100 %:

(a) the stock of the resource will be constant.

(b) the stock is renewable.

(c) the stock is irreversible.

(d) the stock is imperishable.

30- A renewable resource:

(a) will never deplete.

(b) will never exceed a certain stock.

(c) will never exceed certain threshold.

(d) none of the above.

31- Mineral resources:

(a) have an absolute known deposits.

(b) will be depleted very soon.

(c) available stocks can never be expanded.

(d) their deposits can be expanded by discovery and development.

32- Stock resources are different from flow resources in that:

(a) stocks can be measured in point of time not as a time rate.

(b) stocks can be economically utilized but flows can not.

(c) stock resources are not renewable.

(d) flow resources are renewable but stock are not.

33- Natural resources are:

(a) not scarce so they are not economic.

(b) not open access so they are not liable to depletion.

(c) not as scarce as man-made capital.

(d) none of the above.

34- The demand curve shows:

(a) the various quantities of the item that demanders will purchase at alternative prices.

(b) what the quantity demanded will be at the present price.

(c) the principle of diminishing willingness to pay.

(d) all of the above.

35- Markets will not be efficient when:

(a) marginal social benefits are equal to marginal social costs.

(b) market supply curve and the marginal social costs are the same.

(c) the market demand curve and the marginal social benefits curve have to be the same.

(d) none of the above.

36- External costs are defined as:

(a) the difference between private costs and social costs.

(b) the difference between private user costs and public user costs.

(c) the difference between marginal social benefits and marginal social costs.

(d) the difference between marginal private benefits and marginal private costs.

37- The socially efficient rate of output is occurs when:

(a) marginal private costs (MPC) are equal to marginal private benefits.

(b) marginal social costs (MSC) are equal to marginal private benefits.

(c) marginal social costs (MSC) are equal to marginal social benefits.

(d) all of the above.

38- An open-access resource:

(a) leads to over use.

(b) is simply one that is open to restricted use by someone.

(c) is simply one that is open to unrestricted use by someone.

(d) a and b are correct.

(e) a and c are correct.

39- Non sustainable decision is that one which:

(a) makes future generations worse off than present generations.

(b) makes present generations worse off than future generations.

(c) puts current generation at higher difference curve.

(d) puts future generation at advantage.

40- Drawing down of nonrenewable resource is:

(a) necessarily nonsustainable.

(b) may be sustainable.

(c) definitely sustainable.

(d) nothing of the above.

41- Economic efficiency is a situation in which:

(a) net benefits to society are maximum.

(b) total benefits to both current and future generations are maximum.

(c) user cost is accounted for.

(d) marginal cost is as much high as user cost.

42- Dynamic efficiency:

(a) account for both present and future generations.

(b) cope with efficiency pair wise.

(c) cope with efficiency stepwise.

(d) cope with efficiency period wise.

43- User cost is defined as the:

(a) opportunity cost of current consumption as borne by future generation.

(b) the cost borne by the user of the resource to extract the resource.

(c) the cost that is required to cover the discount value of the resource.

(d) the cost the government charge present generations to stop extraction.

44- The higher the discount rate:

(a) the less the user cost.

(b) the higher the user cost.

(c) the higher the social cost.

(d) the lower the current cost.

45- The user cost of extraction from nonrenewable resource:

(a) necessarily greater than that from renewable resource.

(b) necessarily smaller than that from renewable resource.

(c) can not be compared with that of renewable resource.

(d) necessarily less than.

46- Social optimal extraction rate is:

(a) that makes user cost zero.

(b) that makes net social benefit zero.

(c) that makes net social marginal benefit zero.

(d) nothing definitely of the above.

47- At any quantity greater than the optimal:

(a) MSC > MSB.
(b) MSC < MSB.
(c) MSC - MSB < 0.
(d) MSB - MSC > 0.

48- If the discount rate is zero:

(a) the user cost will be negative.
(b) the user cost will be positive but less than one.
(c) the user cost will be negative but less than zero.
(d) nothing of the above will hold.

49- If the nonrenewable resource is indefinitely large in deposits:

(a) the static and dynamic efficiency will be compatible.
(b) the user cost will be zero.
(c) the user cost will be 1.
(d) a , b are correct.

Question # 3: Define the Following:

(1) Optimal environmental quality.

(2) Assimilative capacity.

(3) Ecologically stable output.

(4) The marginal external cost.

(5) The marginal private benefits.

Question # 4: True or False:

(1) Damage to the environment is clearly undesirable.

(2) The marginal private benefit decreases as the level of production increases.

(3) The marginal external cost decreases as output increases.

(4) The optimal level of environment occurs when marginal revenue equals marginal cost.

(5) The level of pollution equals zero when the level of output equals zero.

(6) It would be possible to stop pollution at the expense of stopping all production.

(7) The optimal level of pollution occurs when level of pollution equals zero.

(8) The level of waste increases as the level of production increases.

(9) The optimal level of environment occurs when marginal benefits equal marginal external costs.

(10) The optimal level of environmental quality is unstable point.

(11) Efficient rate of pollution is zero pollution.

(12) To minimize abatement cost all firms have to cut emission rate proportionately.

(13) If equimarginal principle applies, the total cost of abatement will be minimum.

(14) The threshold of most pollutants is zero.

(15) The efficient level of pollution is static.

(16) Equiproportianate cut back on emission give the efficient level of pollution.

(17) Renewable resources are never depletable.

(18) Renewable resource is reversible.

(19) Economics of pollution has nothing in common with economics of depletion.

(20) A renew able resource is one that is replenshible.

(21) Only biological resources are renewable.

(22) Recreation is a non extractive use of the forests.

(23) Non use value is non extractive value but the inverse is not necessarily true.

(24) Pollution could not be reduced to zero.

(25) Not all economic activities are polluting.

(26) Our ecosystem is open so that their is no limit to growth.

(27) Marginal total cost = Marginal current cost + user cost.

(28) The demand curve illustrates the principle of diminishing willingness to pay.

(29) Markets will tend to generate socially efficient output when marginal social benefits are equal to marginal social costs.

(30) The markets must be monopolistic if the markets generate socially efficient output.

(31) External costs are defined as the difference between private costs and social costs.

(32) External benefits are present whenever public goods are involved.

(33) When public goods are involved, private markets will find it difficult to supply socially efficient levels.

(34) External benefits can be present in the same direct way that external costs are present.

(35) Open-access typically leads to over use.

(36) If there are no external benefits, the marginal social benefits curve and the demand curve have to be the same.

(37) Marginal social costs curve is always lower than marginal private costs curve.

(38) Marginal private costs curve and supply curve are the same.

(39) Static efficiency is never compatible with dynamic efficiency.

(40) A timber harvesting has a user cost greater than one. But oil production has a one-to-one user cost.

(41) Static efficiency takes no account of future generations.

(42) The higher the discount rate the greater the bias against future generation.

(43) In poor countries the natural resources are under higher threat of depletion than in rich countries.

(44) Extraction from renewable resources has no user cost.

(45) User cost implies that there is a trade off between current consumption and future consumption.

(46) The non use value of natural resources makes the user cost higher than otherwise.

(47) Discounting future benefits is unjust for future generation.

(48) Positive interest rate is a sign of the natural tendency of discounting the future.

(49) If you are indifferent as between \$ 100 now and \$120 next period then you are positively discounting the future at 20 %.

(50) The farther in the future is the event being considered the lower the discount that people apply to it.

(51) The poor tends to discount the future more heavily than the rich.

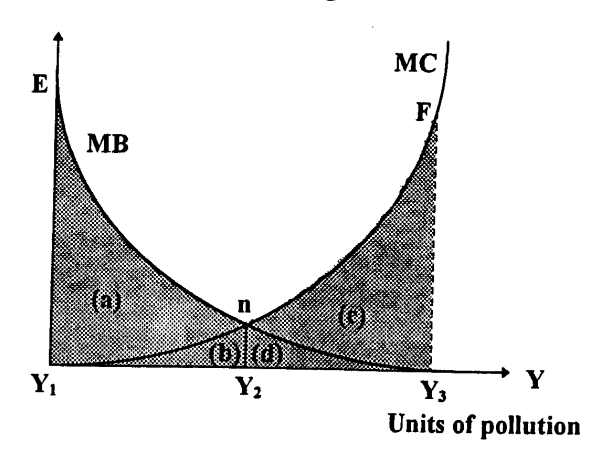
(52) Tropical forests are more likely to be decreased than boreal forests.

(53) Discounting necessarily put the future generation at disadvantage.

(54) Excessive extraction of non renewable resource is inevitably nonsustainable.

Question # 5:

Refers to the following figure :



Where : MB : Marginal benefit of producer the pollution.

MC : Marginal cost of affected person of pollution.

(1) The area EY_1Y_3 represents --------------

(2) The area FY_1Y_3 represents --------------

(3) Y_2 is the equilibrium level of pollution because the affected person is ready to pay the area ---------- in order to have benefit through reducing cost by the larger area ------------- . So that, the level of

pollution ------------- is more beneficial than the level -------- for both ------- and --------

(4) Starting from the level Y_3, a mutually beneficial bargain between two parties is possible, if they agree to reduce pollution to level Y_2. The gains to affected person equal the area --------- + the area ---------. and the loss to the producer equals the area --------. The affected person must pay the area --------- to the producer for compensation. The net benefit for affected person equals ---------, and the net benefit for the producer equals --------- . So, the level --------- is more desirable than the level --------- for both parties through bargaining.

(5) Y_1 is not desirable level of pollution because the loss of producer equals the area -------------- is greater than gains to affected person which equal --------- .

Question # 6: Show Graphically:

(1) Optimal environmental quality.

(2) Optimal environment and assimilative capacity.

(3) The effect of a decreasing in assimilative capacity on the optimal environmental level.

(4) The efficient level of emission.

(5) Enforcement cost increases the level of emission.

(6) Technological change affect the efficient level of emission.

(7) At the efficient level of pollution total cost is minimum.

(8) The economy - environment relationship.

(9) Mechanism of pollution.

(10) Marginal social costs curve (MSC) and the marginal private costs curve (MPC).

(11) Determination of the socially efficient level of output.

(12) The static social optimal rate of extraction.

(13) The intertemporal efficient rate of extraction.

Question # 7:

The following table illustrates the marginal abutement costs of two firms working in the same industry :

Emissions (tons/week)	Marginal abatement costs ($1,000/week)	
	Firm A	Firm B
12	0	0
11	1	2
10	2	4
9	3	6
8	4	10
7	5	14
6	6	20
5	8	25
4	10	31
3	14	38
2	24	58
1	38	94
0	70	160

1- If emission is to be reduced by total 3 units, what will be the efficient marginal costs ?

2- If emission is to be reduced by 12 total units, what will be the efficient marginal costs ?

3- If the marginal costs of abutement is to be 14, how much emission is to be cut for each firm?

Question # 8: Compare and Define:

(1) Extractive vs Non extractive resources.

(2) Use value / non use value of the natural resource.

(3) Environmental economics vs resource economics.

(4) Renewable vs nonrenewable resources.

(5) Recyclability and reversibility of natural resources.

(6) Resource conservation vs resource preservation.

Question # 9:

Some words are missing, you are referred to the main text to find these missing words:

(1) An economy is a system by which a group of people provide themselves with -------- , -------- .

(2) All individuals play two roles in an economy as --------- and ---------- .

(3) Population ecology can be conceived as a collection of interacting populations of organisms that grow and change according to ------------ principles and the impacts of ----------- events.

(4) At any point in time nature can be described by a series of variables specifying the -------- and -------- status of the ecosystem. These variables consist of stock variables such as ------------- , ------------, and flow variables such as ------------- .

(5) The natural resource system can be conceived as a stock of -------- -------- which when combined with

other types of inputs yield useful ---------------- and ---------------.

(6) The relationship between the economy and the nature (environment) is two-way relationship: The ėconomy derives flow of --------------- from the environment for the sake of production. Through production and consumption activities the economy emits back to the environmental system (water, land, air) a flow of ------ .

(7) Natural resources economics is the study of the first flow by the means of the analytical tools of the economic theory. But the study of the second flow is known as ------- ------- .

(8) There is a close relationship between the two kinds of study because what is derived from the environment must be emitted back into the environmental media in different shape but in the same --------------- .

(9) Excessive use of the natural resource inputs will cause ----------------- problem with which in turn cause a --------------- problem.

(10) The depletion problem arises from using some natural resources beyond its capacity to--------------- and the pollution problem arises from too much -------------- dumped into the environment beyond its -------------

capacity.

(11) Conservation is the idea of using natural resources at a rate that is ------- , ------- . But resource development refers to the process of increasing their ------------- to the -------------- --------------- . On the other hand preservation means --------------- .

(12) Any environmental resource may have use value or land non use value. Use value of a forest is such as ------ , ------and nonuse values are such as ---------- , ------- the use values are broken down into ---------- and ------- the extractive use value is defined as ----- and the nonextractive use value means --------------- .

(13) A market is a -------------- by which buyers and sellers negotiate transactions among themselves to transfer the ownership or use of a good or service at agreed upon prices.

(14) The basic market model used to summarize these transactions. The demand curve shows the various quantities if the item that demanders will --------- alternative prices. It is based on the notion of -------- .

(15) The supply curve represents the behavior of sellers of thus good and service. Its upward slope is a reflection of increasing -------------------- .

(16) Given the demand and supply curves, there is only ---------------- where the quantity demand by consumers is the same as that -------------- by producers.

(17) Social efficiency is defined as the rate of output at which marginal social benefits (MSB) are equal to marginal social costs (MSC). The market demand curve and the ------------- curve have to be the same, and the market supply curve and the ------------------ curve have to be the same.

(18) Market will tend to generate socially efficient output if ------------------ equals ------------------- . And the markets will not be efficient if ------------------- does not equal ------------------- .

(19) The difference between private costs and social costs is called -------------- . External costs are costs incurred by people who are not party to the decisions that give rise to them.

(20) External benefits can be present in the same direct way that ----------------- are present. External benefits are present wherever public goods are involved. A public good is a good that, one made available to one person, automatically becomes available to others. When public goods are involved, private markets will find it dif-

ficult to supply efficient levels. Because of the nature of the public goods, it now becomes possible for the individuals to free ride. Free riding means holding back on one's contribution so as to get the benefits while bearing less of the cost.

(21) A situation is efficient in the static sense if it is efficient strictly from the view of --------------- . But dynamic efficiency means a situation that not only takes into account the present but also the future efficiency. A decision is efficient if it takes into account all the ------- flowing from it whether occurring now or in the future.

(22) If there are no future consequences stemming from today's decision then, ------------- ------------- is equivalent to ------------- ------------- .

(23) Maximizing the yield from one piece of land in this season has no effect on the coming season yield so ------------- efficiency in agriculture implies --------- ------------- . But cutting the tree this year affect the consumption of wood over the next period, thus static efficiency in logging does not necessarily imply ------- ------------- .

(24) The rate of output is socially efficient when it yields the maximum and this happen when marginal social benefits equal ------ --------- ---------- .

(25) Graphically total social benefit is the area under the aggregate marginal willingness to pay curve. But total social cost is the area under ------------ ------------ ------------. ------------.

(26) Static social efficiency occurs at the intersection of the marginal --------- --------- ---------- ---------- and --------- --------- ---------- pertaing to the -------------- period.

(27) Intertemporal efficiency requires that :

Present value of --------- ---------- = Net benefits in year 0 + $\frac{1}{1+r}$ Net benefits in year 1 + --------- Net benefits in year 2 + -------------. or present value of net benefits = Net benefits in year 0 + Σ all ---------- --------- ---------- .

(28) In terms of the marginal analysis the above equation can be rewritten as :

Marginal net benefit = Marginal benefit - Marginal current cost + ----------- .

(29) User cost is defined as the change in the ----- ------ --------- of future net benefits resulting from --------- decision. Therefore the user cost will be zero if current decision bears nothing on -------- net -------- .

(30) Discounting future benefits means that present generation attaches less value to the ------------ benefits.

(31) Sustainable development is development that meets the needs of ------------ without ------------ the ability of future generation to meet their own needs.

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